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AN EVALUATION OF THE ECONOMIC BENEFITS DERIVED FROM THE IMPROVEMENT OF WATER QUALITY IN CONTRA COSTA CANAL

Public Health Service
San Francisco, California

30 June 1962

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PB 228 695

KELLOGG RESERVOIR

WATER QUALITY CONTROL PROJECT

AN EVALUATION OF THE ECONOMIC BENEFITS DERIVED FROM THE IMPROVEMENT OF WATER QUALITY IN CONTRA COSTA CANAL

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

REGION IX

PUBLIC HEALTH SERVICE

BUREAU OF STATE SERVICES

DIVISION OF WATER SUPPLY AND POLLUTION CONTROL

SAN FRANCISCO, CALIFORNIA

June 30, 1962

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ADDENDUM 1

INCREASE IN HARDNESS IN THE PROPOSED KELLOGG RESERVOIR DUE TO EVAPORATION AND RUNOFF

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
REGION IX
PUBLIC HEALTH SERVICE
BUREAU OF STATE SERVICES
DIVISION OF WATER SUPPLY AND POLLUTION CONTROL
SAN FRANCISCO, CALIFORNIA

APRIL, 1963

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ADDENDUM 1

INCREASE IN HARDNESS IN THE PROPOSED KELLOGG RESERVOIR DUE TO EVAPORATION AND RUNOFF

Introduction

The report "An Evaluation of the Economic Benefits Derived from the Improvement of Water Quality in Contra Costa Canal", prepared by the U. S. Department of Health, Education and Welfare, Region IX, Public Health Service, Bureau of State Services, Division of Water Supply and Pollution Control, San Francisco, California estimates economic benefits which will be derived from improving the quality of waters in the Contra Costa Canal by augmenting Contra Costa Canal waters with high quality waters stored in the proposed Kellogg Reservoir. Additional information obtained subsequent to the writing of the report indicates that stored waters in the Kellogg Reservoir may increase significantly in hardness as a result of runoff and evaporation. The estimated economic benefits to be derived from the proposed project might seriously be affected if this condition were to prevail. This addendum discusses the effects of runoff and evaporation on impounded waters in the proposed Kellogg Reservoir and presents conclusions which have been incorporated in the above report.

Increase in Hardness due to Evaporation and Runoff

The drainage basin of the proposed Kellogg Reservoir is underlain with cretaceous sediments. Runoff waters from this area can be expected to contain significant quantities of carbonate and bicarbonate hardness. An increase in average hardness of the impounded waters in the proposed Kellogg Reservoir will result if runoff waters containing high hardness concentrations are mixed with the stored low hardness waters. Evaporation will also concentrate chemical constituents resulting in added increases in hardness.

In addition, changes in hardness in Kellogg Reservoir are related to reservoir operational schedules, and the hardness of the Delta-Mendota water placed in the reservoir. The effects of runoff will be most severe when the quantity and hardness of the Delta-Mendota water is a minimum. Table 1 indicates the computed effect of both evaporation and runoff on increase in hardness for the reservoir operational schedules, Series F and Series G, and Delta-Mendota water hardness.

The evaporation loss per year was taken as 8000 acre-feet as estimated in the preliminary schedule. This quantity of evaporation would increase the hardness of the 122,000 and 259,000 acre-feet of Delta-Mendota influent for the two different operating schedules by the amount shown in the table.

The increased hardness resulting from runoff was estimated by determining the increased hardness of the Delta-Mendota water pumped annually to the reservoir when it is mixed with the annual runoff (estimated hardness 200 ppm). Considering Delta-Mendota water with an average of 100 ppm, the average increase in hardness due to runoff would be about 4 ppm under Series F and 2 ppm under Series G. These values, which were computed from the values in Table 1, take into consideration the effect of annual variations in runoff. Under these same conditions, the effect of evaporation is an increase in hardness by 7 ppm and 3 ppm respectively.

Conclusions

The combined effect of evaporation and runoff will be to increase the hardness of water stored in Kellogg Reservoir by 11 ppm under Series F operation, and 5 ppm under Series G operation. Practically the same total increase in hardness will result, regardless of the Delta-Mendota water hardness. This is due to the fact that with softer Delta-Mendota water, the effect from evaporation decreases,

TABLE 1

ESTIMATED EFFECT OF RUNOFF AND EVAPORATION
ON KELLOGG RESERVOIR HARDNESS

Average Hardness Delta-Mendota Water ppm	Hardness Increase in Reservoir due to Evaporation and Runoff - ppm							
	Series F-122,000 AF/Year from Delta-Mendota Canal				Series G-259,000 AF/Year from Delta-Mendota Canal			
	Due to Evap.	Due to Runoff Based on			Due to Evap.	Due to Runoff Based on		
		Avg. Rainfall	Max. Rainfall once in 5 yrs.	Max. Rainfall once in 20 yrs.		Avg. Rainfall	Max. Rainfall once in 5 yrs.	Max. Rainfall once in 20 yrs.
40	3	4	14	18	1	2	7	9
60	4	4	12	16	2	2	6	8
80	6	3	10	13	2	2	5	7
100	7	2	8	11	3	1	4	6
120	8	2	6	9	4	1	3	4

while that from runoff increases a similar amount. With increasing hardness, just the opposite compensating effect will result.

The above results have been incorporated in the subject report. Hardness reductions attributed to the operation of the project, average annual per capita cost savings, and total municipal and industrial benefits accruing from operation of the proposed Kellogg Reservoir reflect the changes in hardness characteristics due to the concentrating effects of runoff waters and evaporation.

A similar increase in chloride concentrations can be expected from the concentrating effect of evaporation. The incremental increase that would result, however, would not increase the average chloride concentration of the impounded water in the Kellogg Reservoir above the 100 ppm standard from which the industrial benefits are based. Thus, there would be no change in unit benefits accruing to industrial consumers.

I. ACKNOWLEDGMENTS

We gratefully acknowledge the cooperation and assistance given by various Federal, State, and local agencies and by the industrial firms in Contra Costa County. Special thanks are extended to the staff members of the Contra Costa County Water District, Mr. John E. DeVito, Assistant Manager, in particular, to personnel of the Tracy Field Division, and of the Region 2 office of the Bureau of Reclamation, and to the City officials of the many communities in the study area. In addition, valuable assistance was obtained from Dr. Gerald T. Oriob, Consulting Engineer, and Dr. Rolf A. Eliassen, Professor of Civil Engineering, Stanford University.

II. INTRODUCTION

The Contra Costa Canal, serving a water use area along the south side of Suisun Bay, obtains its water from Rock Slough in the Sacramento-San Joaquin River Delta area of California. In 1940, when the canal was constructed, the quality of the water at this source was acceptable throughout most of the year. During certain periods of recent years, however, the quality of the water has been deteriorating due to increasing concentrations of chlorides and total dissolved solids. Roughly, the periods of concern have been the months of January, February, and March, when the surface runoff and higher stream flows flush accumulated salts, minerals, and sediments from upland areas through the Delta region to the ocean, and during the months of July, August, and September, when upstream water demands decrease the fresh water flow to the ocean and saline waters intrude into the Delta region. As upstream irrigation and other water uses are continually being intensified with subsequent increases in waste discharges, it is anticipated that the water available to the Contra Costa Canal will be further impaired in quality for increased periods of time.

The Bureau of Reclamation of the U.S. Department of the Interior is investigating the feasibility of the construction of a reservoir on Kellog Creek in Contra Costa County as a possible means of improving the quality of water in the canal. Better quality of water stored in this reservoir would be released as needed to dilute poorer quality of water obtained at the canal intake during certain periods, thus providing to municipal, industrial, and other users water which at no time would contain more than 100 parts per million (ppm) of chlorides or 400 ppm of total dissolved solids.

Section 2 of Public Law 660 as amended by Public Law 87-88 states in part as follows:

> "In the survey of planning of any reservoir by the Corps of Engineers, Bureau of Reclamation, or other Federal agency, consideration shall be given to inclusion of storage for regulation of stream flow for the purpose of water quality control.....
>
> "The need for and the value of storage for this purpose shall be determined by these agencies with the advice of the Secretary (of the Department of Health, Education, and Welfare), and his views on these matters shall be set forth in any report or presentation to the Congress, proposing authorization of construction of any reservoir including this storage."

Relative to this provision, and in response to discussion with representatives of Region 2 of the Bureau of Reclamation, the Department of Health, Education, and Welfare, Public Health Service, Region IX, via a letter dated January 11, 1962, offered assistance in the evaluation of present and anticipated future needs for and the economic value of improvements in quality of water for municipal and industrial use in connection with the Bureau of Reclamation's feasibility study of Kellogg Reservoir.

By letter of January 18, 1962, the Regional Director of Region 2, Bureau of Reclamation, accepted the offer. This report contains the determinations and conclusions of the Department of Health, Education, and Welfare, Public Health Service, in regard to that study.

III. SUMMARY OF CONCLUSIONS

1. Upstream depletions, related salinity intrusions, and poor quality return flows are causing water quality deterioration in the Delta. Municipal, industrial, and agricultural users from the Contra Costa Canal have been affected adversely by this deterioration.

2. Construction of the proposed Kellogg Reservoir and its operation according to operation schedules developed by the Bureau of Reclamation will improve the quality of water in the Contra Costa Canal. Widespread benefits from this improvement will accrue to municipal, industrial, and agricultural users in the Canal service area and to the general economy of the region.

3. Municipal Benefits - Unit benefits derived from improvement in canal water are based on the reduction in the amount of soap or synthetic detergent necessary in household and commercial cleansing operations, and the reduction in the cost of operation, servicing, and amortization of individual home softeners. Unit benefits were computed for the Kellogg project alone and for the Kellogg project when in conjunctive operation with the State of California's Delta projects and the Bureau of Reclamation-State of California San Luis project. Municipal unit benefits resulting from the improvement in water quality are as follows:

Period	Classification of Benefit	Average Annual per capita Costs Savings
I. Kellogg Project Alone	(a) Reduced use of soaps, detergents, etc.	$ 0.65 *
	(b) Reduced use of home softeners	17.03 **
II. Kellogg Project in conjunctive operation with Delta and San Luis Projects	(a) See above	0.096
	(b) See above	--

*Value pertains to 98.25% of population. **Value pertains to 1.75% of population.

The proposed project may have a detrimental effect on the taste and odor characteristics of the water unless essential steps are taken to control the growth of algae in the reservoir. The costs for algae control should be considered as a detriment and therefore should be subtracted from the benefits of the Kellogg project. These costs are as follows:

Period	Annual Detriment
I. Kellogg Project Alone	$ 57,000
II. Kellogg Project in conjunctive operation with Delta and San Luis Projects	53,200

Unit benefits stated above should be applied to projections of population served by the Canal which are shown in Table 7 of this report. The population projections increase from the actual 1960 population figure of 141,000 to 918,000 in 2020. Total municipal water use is expected to increase from 21,306 acre-feet in 1960 to 159,440 acre-feet in 2020.

4. Industrial Benefits - Unit benefits accruing to industrial consumers are based on penalty cost data obtained from the major industrial water users in the Contra Costa Canal service area for the calendar year 1961. These unit benefits are as follows:

Period	Average Annual per AF Costs Savings
I. Kellogg Project Alone	$ 7.65
II. Kellogg Project in conjunctive operation with Delta and San Luis Projects	1.79

Two industrial water use projections are presented in this report. The first, based upon the present water use per acre of development land as related to the anticipated development of available industrial land, ranges from an actual water use of 42,726 acre-feet in 1960 to an anticipated water use of 255,000 acre-feet in 2020. These figures were derived through the joint

efforts of the Contra Costa County Water District, the Bureau of Reclamation and the Public Health Service. The second projection is derived from the California Department of Water Resources Bulletin No. 76. This projection increased from the actual water use of 42,726 acre-feet in 1960 to an estimated value of 477,000 acre-feet in 2020. For the purpose of estimating total monetary benefits resulting from water quality improvement caused by the proposed Kellogg project, it is recommended that the more conservative projections be used.

5. Agricultural Benefits - Projected improvement in water quality characteristics due to the proposed Kellogg Project indicate that there is a potential benefit to the agricultural users. However, the determination of this benefit was not possible with the information presently available.

6. A summary of the benefits accruing to municipal and industrial water users in the Contra Costa Canal service area is shown in the following table:

TOTAL MUNICIPAL AND INDUSTRIAL BENEFITS
ACCRUING FROM OPERATION OF KELLOGG RESERVOIR*

Year	Kellogg Reservoir Operating Alone	Kellogg Reservoir With San Luis Unit
1968	$ 688,000	$ 688,000
1970	748,000	748,000
1980	1,093,000	1,093,000
1990	1,522,000	305,000
2000	1,862,000	374,000
2010	2,338,000	461,000
2020	2,805,000	544,000

*Figures to nearest thousand.

7. The water in Contra Costa Canal usually meets the 1962 Public Health Service Drinking Water Standards. Concentrations of certain constituents do, however, occasionally exceed the recommended concentrations. It

is, therefore, recommended that a sampling program be initiated and continued until the origin and frequency of occurrence of these constituents can be determined.

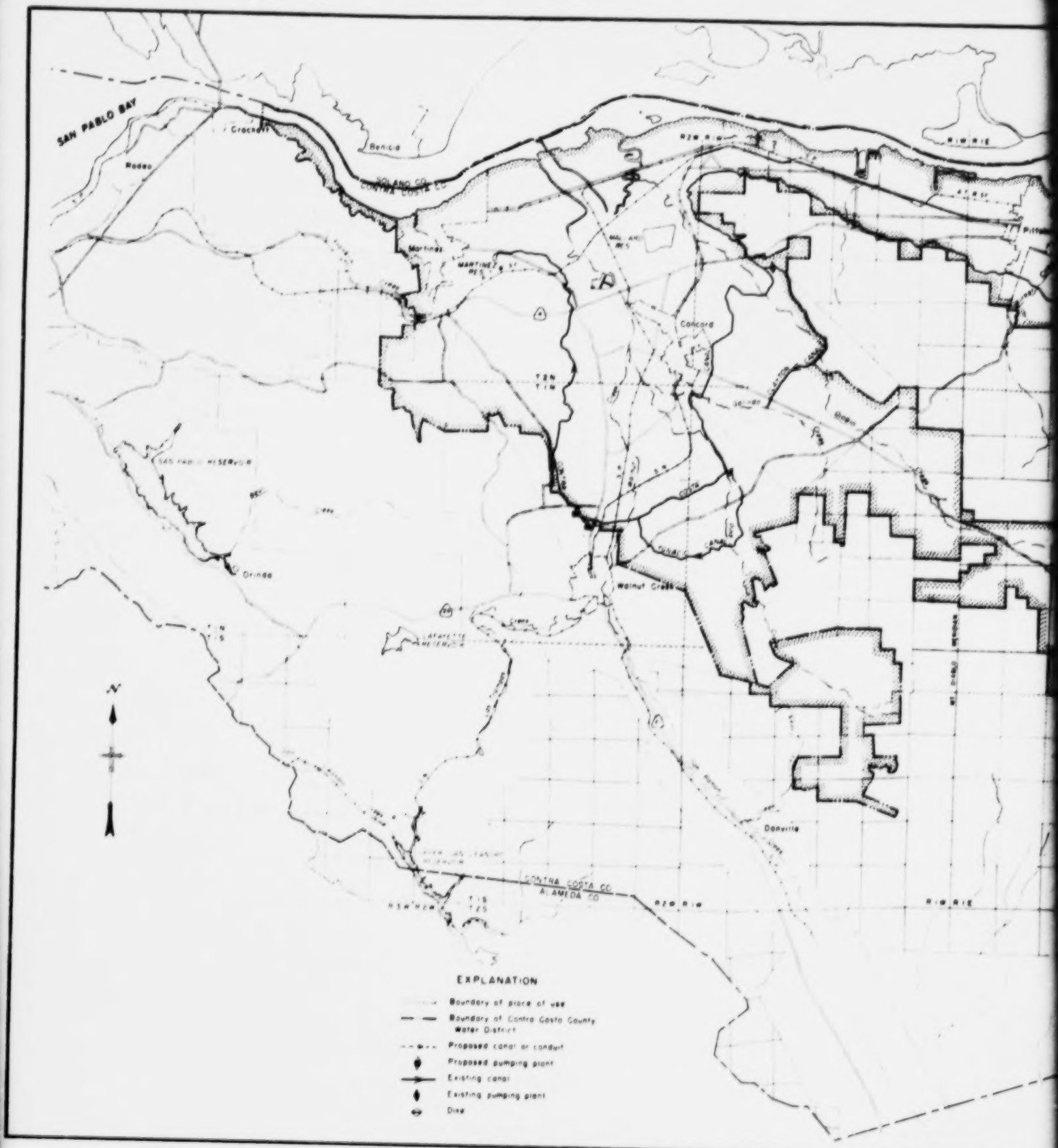
8. It is recommended that the many drains that enter Contra Costa Canal be relocated to prevent the possible and probable pollution from surface runoff. These changes in drainage patterns will help maintain the high quality of water that will be supplied to Contra Costa Canal through the operation of the proposed Kellogg Reservoir.

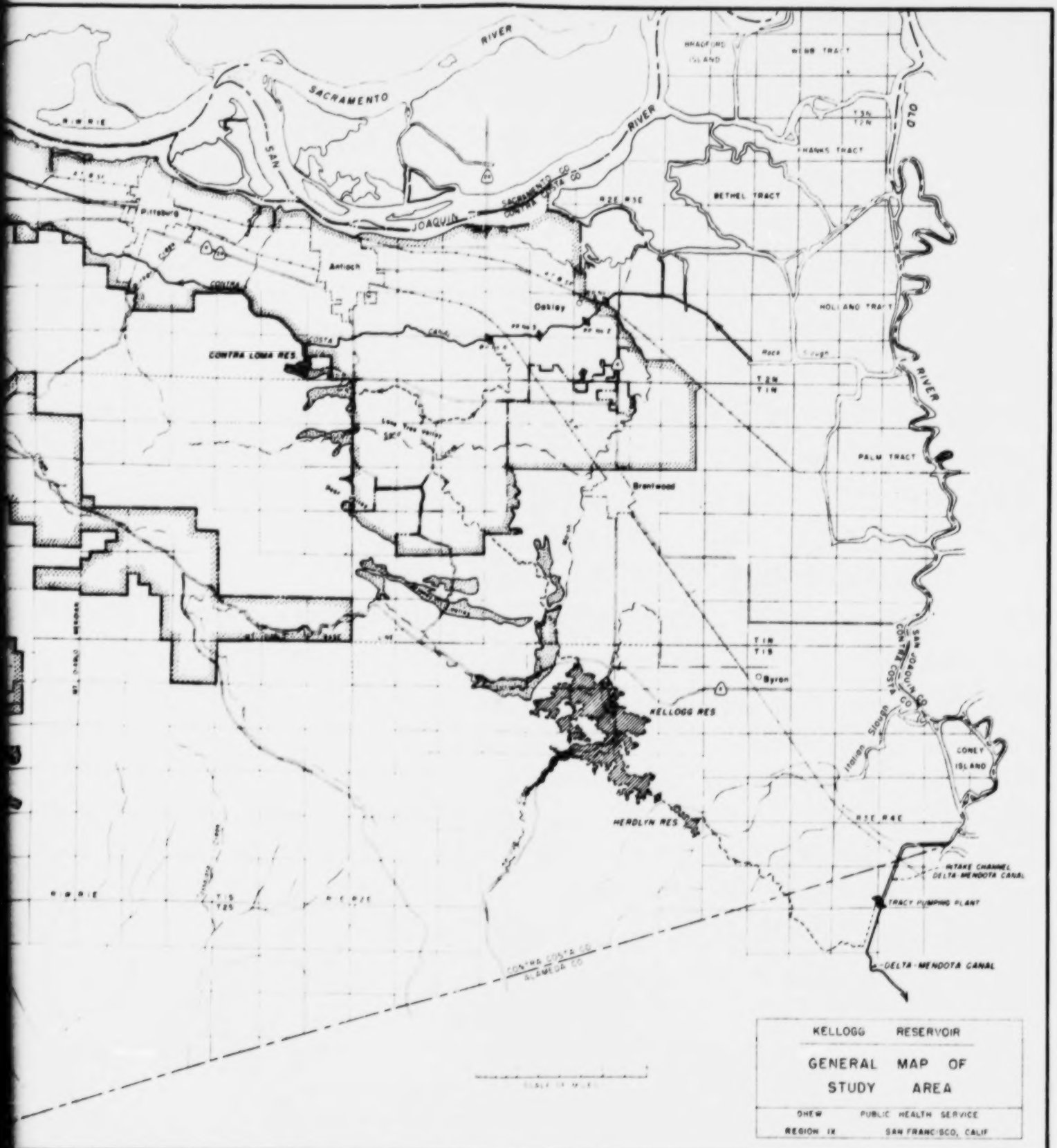
IV. DESCRIPTION OF STUDY AREA

Contra Costa County is situated across San Francisco Bay from San Francisco. The County is north from Oakland and Berkeley, partially separated by a low range of hills and fronts on San Francisco, San Pablo, and Suisan Bays, Carquinez Strait, and the San Joaquin River with more than 70 miles of waterfront. The interior of the 734-square mile county is an area of hills and valleys with the elevation ranging from sea level to 3,849 feet (Mt. Diablo).

The climate of the county is characterized by mild, wet winters and hot, dry summers. Climatic conditions of the specific study area of this report resemble those of the Central Valley, with less rainfall, more "tule" fog, and higher and lower temperatures than the coastal areas. The frost-free season has averaged 270 days at Brentwood. Seasonal precipitation is exceedingly variable from month to month as well as between areas in the county. However, 90 percent of all rainfall occurs during the period of November through April. The average seasonal amount varies from 12 inches at the eastern end of the county to 30 inches at the summit of Mt. Diablo. Prevailing winds are from the west, except during the first three months of the year when they tend more to the south and east. Clear days predominate through the year. Surface drainage is accumulated in small intermittent streams which transverse the county from south to north and drain into the San Joaquin River.

The specific study area of this report is the present and potential service area of the Contra Costa County Water District. This area is located along the eastern and northern boundaries of the county with a section extending well into the middle of the county (see map, page 9).


SAN PABLO BAY
Crockett
Benicia
Rodeo
Martinez
Concord
Orinda
Walnut Creek
Danville
CONTRA COSTA CO
ALAMEDA CO
EXPLANATION
Boundary of place of use
Boundary of Contra Costa County Water District
Proposed canal or conduit
Proposed pumping plant
Existing canal
Existing pumping plant
Dike


SACRAMENTO RIVER
SAN JOAQUIN RIVER
OLD RIVER
WEBB TRACT
THORNTON
THANKS TRACT
BETHEL TRACT
HOLLAND TRACT
PALM TRACT
Antioch
Oakley
Brentwood
Byron
CONTRA LOMA RES
KELLOGG RES
HERDLYN RES
CONEY ISLAND
INTAKE CHANNEL DELTA-MENDOTA CANAL
TRACY PUMPING PLANT
DELTA-MENDOTA CANAL
CONTRA COSTA CO.
ALAMEDA CO.
KELLOGG RESERVOIR
GENERAL MAP OF STUDY AREA
DHEW PUBLIC HEALTH SERVICE
REGION IX SAN FRANCISCO, CALIF

Contra Costa County Water District is served through the facilities of the Contra Costa Canal. This canal, which was placed in service in 1940, is an integral part of the Central Valley Project as developed by the U.S. Bureau of Reclamation.

Contra Costa Canal receives its supply from Rock Slough. It has a length of 47.8 miles and is concrete lined. The sole purpose of the canal is to provide a water supply to the municipal, industrial, and agricultural users of the water district.

The present population of the water district is estimated to be about 141,000. There are 11 towns and cities within the water district's boundaries. Antioch, Martinez, Concord, Pittsburg and Pleasant Hill are incorporated. Oakley, Nichols, Port Chicago, Avon, Port Costa and Pacheco are unincorporated. These cities and a number of tracts that have been subdivided into small city-lot-type homesite developments, both adjacent to established communities and in the rural areas, represent the population concentrations in the district.

The industries in the study area are varied. They range from light to heavy and include petroleum refining, fish and vegetable canning, chemical production, sheet metal production, steel processing, paper manufacturing, and electrical power generation.

V. DESCRIPTION OF PROJECT

Contra Costa Canal

In 1930, the agricultural, municipal, and industrial development in Contra Costa County had progressed to the point where all local water supplies would soon be exhausted. The California State Water Plan which was being developed at that time stated, "This section (of the State) is suffering from an insufficient water supply which cannot be remedied by additional development of local water resources." Therefore, a conduit was proposed for the eastern Contra Costa County area in the State Water Plan. The "Contra Costa Conduit" was to have a capacity of 120 cubic feet per second (cfs), of which 34 cfs were allocated for industrial and municipal purposes, and 86 cfs for irrigated agriculture. At that time, there were 13,000 acres of developed orchards and vineyard lands considered in immediate need of a supplemental irrigation water supply. The provision for a canal capacity of 120 cfs was considered sufficient to take care of the immediate and urgent water demands in the limited area then planned to be served.

In 1935, further studies were made on the design, location, and capacity of the "Contra Costa Conduit" as part of the Bureau of Reclamation's Central Valley Project. By this time, the proposed capacity was 275 cfs which was deemed necessary to meet the future demands for 25-30 years. The Contra Costa Canal was finally designed and constructed by the Bureau of Reclamation with a capacity of 350 cfs in order to meet the estimated ultimate water demands of the area in and adjacent to the present water district.

The Contra Costa County Water District was organized on May 5, 1936, in anticipation of construction of the Canal in order to provide

administration for the district and to create a legal entity which could contract with the Federal Government for the purchase and distribution of water. The canal is owned and operated by the Bureau of Reclamation. The water district as originally organized contained about 48,000 acres along the south shore of Suisun Bay. At the present time, the total area is approximately 99,500 acres. The first water delivered through the canal was in the fall of 1940.

Contra Costa Canal receives its supply from Rock Slough which leads westerly from one of the main channels of the San Joaquin River (see map). These first four miles of the canal are earth lined. At Oakley, the first pumping plant lifts the water out of the inlet channel to the first concrete lined section of the canal. In the next three miles, three additional pumping plants lift the water a total of about 128 feet to the canal's maximum elevation. From this point, the flow through the 47.8-mile canal is by gravity to the terminal reservoir at Martinez. The canal has a capacity which decreases gradually from 350 cfs at the intake to 22 cfs at the terminal reservoir. The two tributary canals--Ygnacio and Clayton--were constructed to supply users who would otherwise have difficulty in obtaining water from the main canal. Data for the canals and wasteways are given in the following table.

TABLE I

PHYSICAL FEATURES OF THE
CONTRA COSTA CANAL SYSTEM

Feature	Length (miles)	At Intake			At Terminal		
		Bottom Width (ft)	Depth (ft)	Capacity (cfs)	Bottom Width (ft)	Depth (ft)	Capacity (cfs)
Contra Costa Canal	48.0	24.0	6.5	350	3.0	1.84	22
Clayton Canal	4.5	4.0	2.19	42	3.0	1.65	11
Ygnacio Canal	5.1	5.0	1.87	30	3.0	1.24	9
Los Mendanos Wasteway	1.7	12.0	6.0	310	12.0	6.0	316
Nichols Wasteway	1.1	16.0	3.7	225	16.0	3.7	225

Galindo Creek Wasteway - Natural Stream
Walnut Creek Wasteway - Natural Stream
Martinez Reservoir - Capacity 270 acre-feet

Nature of the Problem

When Contra Costa Canal was first constructed the quality of Central Valley Project water at its source, Rock Slough, was acceptable throughout most of the year. During certain periods in recent years, however, the quality of water has been deteriorating due to increasing concentrations of chlorides and total dissolved solids. The water quality degradation became more apparent beginning in 1953. This was due to the beginning of an era of increasing municipal and industrial demands upon the system. During that year and the years following a number of major industries located along the canal. The total industrial water delivered from the canal increased from 9,812 acre-feet (AF) in 1952, 15,700 AF in 1953, to 41,000 AF in 1961.

An historical review of water quality degradation in the canal (see Table 2) indicates that the number of days of poor quality water is increasing as is the percentage of the total poor quality water delivered. This is because peak production and peak water requirements generally occur during the months of high chlorides and high total dissolved solids --

TABLE 2
CHLORIDE CONTENT PER NUMBER OF DAYS
AND PER QUANTITIES OF WATER DELIVERED
AT CONTRA COSTA CANAL PUMPING PLANT NUMBER ONE*

(QUANTITIES IN ACRE-FEET)

Year	Under 100 PPM		Over 100 PPM		Over 150 PPM		Over 200 PPM		Over 250 PPM		Over 300 PPM		Over 350 PPM		Annual Total	
	Days	Quantity	Days	Quantity	Days	Quantity	Days	Quantity	Days	Quantity	Days	Quantity	Days	Quantity	Days	Quantity
1945	341	13,650	24	735											365	14,385
1946	291	13,600	74	2,606											365	16,206
1947	138	9,509	227	14,559	70	5,647	33	2,987							365	24,068
1948	222	17,022	144	8,930	46	2,483	3	131							366	25,952
1949	153	18,391	212	17,407	68	5,908									365	35,798
1950	211	21,177	154	9,218	33	1,130									365	30,395
1951	217	23,754	148	7,335	39	1,564	3	91							365	31,089
1952	204	20,081	161	11,167	61	3,459	13	677	2	61	1	61			366	31,248
1953	218	24,694	147	10,320	3	240									365	35,014
1954	178	22,312	187	19,869	34	5,933									365	42,181
1955	198	30,579	167	18,771	27	2,862									365	49,350
1956	273	37,650	93	7,532											366	45,182
1957	275	45,301	90	8,535	12	1,187									365	53,836
1958	264	42,549	101	7,914	7	547									365	50,463
1959	225	42,594	140	28,684	58	16,987	40	12,751	28	9,401	21	7,375	10	3,666	365	71,278
1960	202	44,160	167	32,893	58	13,456									366	77,053
1961	221	48,158	144	31,065	80	20,466	32	10,483	23	7,576					365	79,223

*Date of first delivery was August 17, 1940
The quality of water records (chlorides) began June 12, 1944

July, August, and September. For example, for the years 1956 through 1958 the chloride content was over 100 ppm an average of 26 percent of the time during which 16 percent of the total yearly water use was delivered. For the years 1959 through 1961, the chloride content was over 100 ppm 41 percent of the time. During this three-year period, 41 percent of the water supplied through the canal was in excess of 100 ppm chlorides, and 8 percent exceeded the USPHS Drinking Water Standards for chloride content.

Complaints with respect to the water quality usually originate with industry as the chlorides exceed 100 ppm, immediately followed by domestic purveyors and the general public, and finally by the agricultural users when chlorides approach the 200 mark.

Typical water quality complaints are as follows:

Municipal - Taste, odor, and color. Complaints from people due to no-salt diets and heart conditions, etc. Damage to sensitive nursery plants and flowers. Hardness complaints as such affect clothes and dishwashing.

Agricultural - Irrigators express concern of chloride buildup in the root zone of plants and also complain that due to high chlorides they are forced to use additional waters for leaching purposes.

Industrial - Sustain significant production losses on some products due to high mineral content of Canal water. High turbidity and extreme quality changes affect treatment costs. High NaCl content in the Canal water causes continuous regeneration of the sodium zeolite softeners, resulting in hardness breakthrough to the boilers and generating serious and costly scale problems. Necessity for additional blow-down to cooling towers. Due to hardness and chlorides, demineralizing facilities are unable to supply the demand for high-quality boiler feed water, thereby creating the

necessity to activate at higher operating costs idle low-pressure boilers capable of handling lower quality feed water.

As a result of these complaints, the Contra Costa County Water District approached the Bureau of Reclamation relative to improving the quality of water in the Canal system. In accordance with a cooperative contract, the Bureau of Reclamation initiated investigation of the Kellogg Reservoir Project. This project is described below.

Proposed Project

The proposed project is the construction of multi-purpose Kellogg Reservoir to be located on Kellogg Creek in eastern Contra Costa County (see map, page 9). The multi-purpose developments include water quality control, hydroelectric power, flood control, recreation, and fish and wildlife. The reservoir will be created behind Kellogg Dam and ten saddle dikes. The main features of the dam are as follows:

Type: Zoned earthfill	
Height above streambed	170 feet
Crest length	1,750 feet
Maximum capacity at elevation 300 feet	135,000 acre-feet
Minimum capacity March through September at elevation 274 feet	90,000 acre-feet
Minimum active capacity at elevation 245 feet	50,000 acre-feet

The other works involved in this project include a two-way concrete-lined canal of 800 cfs capacity leading from an 800 cfs pumping plant to Herdlyn Dam. The pumping plant will be located on the intake channel of the Delta-Mendota Canal adjacent to the existing Tracy Pumping Plant. Herdlyn Reservoir will have a maximum capacity of 1,740 acre-feet, a minimum capacity of 1,700 acre-feet, and will fluctuate only 0.20 feet. Connecting Herdlyn and Kellogg Reservoirs will be a 2,400 cfs intake channel supplied by an 800 cfs pump-turbine.

Contra Loma Canal is the main outlet from the reservoir. This 1,200 cfs concrete-lined canal leads northwesterly to Contra Loma Reservoir which will be located approximately two miles south of Antioch. Contra Loma Reservoir will have a maximum capacity of 2,200 acre-feet and a minimum capacity of 500 acre-feet. Concrete-lined Laurel Canal will divert a maximum of 300 cfs from Contra Loma Canal and will head northeasterly to enter Contra Costa Canal at Pumping Plant No. 4.

This project will be able to develop and maintain the quality of water within the chloride limit of 100 ppm or maximum total dissolved solids of 400 ppm. With the storage in Kellogg Reservoir, water can be selected from the Delta and stored during periods of better quality. During these same periods, better quality water can be delivered directly from the Delta to the users of Contra Costa County Water District. When only poorer quality of water is available in the Delta, the pre-selected water in storage can be delivered.

After the San Luis Unit of the Central Valley Project is in operation, it is anticipated that the quality of Delta water in the vicinity of the Contra Costa Canal will improve because of increased dilution by northern California water developed by the Central Valley Project. In this way, a smaller portion of the Contra Costa County Water District's annual demand can be served from the carryover storage in Kellogg Reservoir.

Recreational use of the reservoir is expected to be an important development as a result of this project. It is probable that other facilities for recreation will be developed in addition to any basic facilities that would be provided by the Federal Government.

Basic Assumptions

The findings of the investigation are based on the following assumptions:

a. That no other sources of supply were available and hence the water quality improvement objectives can only be fulfilled via the Kellogg Reservoir Project.

b. That the Bureau of Reclamation is operating the Central Valley Project in such a manner as to have an overall beneficial effect on the Central Valley of California, and that this operation will continue until the San Luis Project is completed, at which time the overall Central Valley Project operation will be altered.

c. That adequate quantities of water will remain available in the Kellogg Reservoir for the purpose of water quality control.

VI. ECONOMIC DEVELOPMENT AND POPULATION GROWTH

Introduction

In December 1959, the U.S. Department of Commerce published a report titled "Future Development of the San Francisco Bay Area--1960 - 2020." A close examination of this report, augmented by discussions with officials in the several sections of the study area and studies of reports by consulting engineers and other agencies, indicated that the general premises and conclusions of the Commerce report are acceptable for the current study. Therefore, the population projections of that report are used in this study. The methods and procedures followed in preparing the Commerce report are described in Chapters II-IV and the appendices of that report. In general, the Commerce Department report involved: (1) determination of the future extent of national population and economic growth; (2) estimation of the share of such future national growth that the San Francisco Bay Area could reasonably be expected to obtain; (3) projection and distribution of population by minor civil divisions in the Bay Area; and (4) check of the estimates and projections derived against estimates of probable future economic growth and against historical population and density-growth experiences of both the Bay Area and of other mature metropolitan areas in the United States, and finally, checks against the amount and type of available land. Because the Commerce Department report covers the present economic base of the Bay Area in detail, this study will present only a brief summary.

Economic Base

The economy of Contra Costa County is multi-sectoral with the principal contribution from oil, steel, chemical and paper companies, in addition to agriculture. Some production and employment data are listed in Table 3.

TABLE 3

CONTRA COSTA COUNTY EMPLOYMENT
BY INDUSTRY GROUP 1/ 2/
FOR SEPTEMBER 1960

INDUSTRY	EMPLOYMENT
Agriculture Services, Forestry, Fisheries	272
Mining	245
Contract Construction	8,871
Manufacturing	28,994
Transportation and Other Public Utilities	5,420
Wholesale Trade	2,495
Retail Trade	13,102
Finance, Insurance, and Real Estate	2,518
Services	7,528
Unclassified Establishments	131
	69,576

1/ Excludes self-employed and railroad employees
2/ Source: State of California, Department of Employment
Research and Statistics Office, Coastal Area

The area being studied in this report consists of only a part of the population, and hence employment in Contra Costa County. In addition to available employment in the county, many wage-earners go outside the county to the other Bay Area counties, particularly San Francisco and Alameda, for employment.

The extent of this employment outside the county, and the study area, is not presently determined.

Because of the possibilities of employment outside the study area, projections of population and economic growth have to consider two areas of economic development: the study area and the regional area. Therefore, economic development and population growth in the study area can be attributed to changes in both economies.

Present Population

Table 4 shows the 1960 population of the area adjacent to Contra Costa Canal as taken from the 1960 Census County Division. Of this 164,076 people

it is assumed for purposes of this report that approximately 141,000 people located in the census divisions are served by the Contra Costa Canal.

TABLE 4

POPULATION OF AREA ADJACENT TO CONTRA COSTA CANAL, BY CENSUS COUNTY DIVISIONS: 1960

Alamo-Danville Division	12,692
Ambrose Division	8,569
Antioch Division	19,175
Concord Division	49,309
Martinez Division	20,967
Oakley-Bethal Division	4,998
Pittsburg Division	21,190
Pleasant Hill Division	22,287
Port Chicago Division	2,432
Walnut Creek Division	
Pleasant Hill (U)	2,457
Total	164,076

Source: U.S. Department of Commerce, Bureau of Census, "US Census of Population - 1960 - California"

Potential Economic Growth

Possibilities for Growth: Contra Costa County, and consequently the study area, is adequately provided with the necessary resources for economic growth. Transportation, fuel and power, and labor supply are either already available or will readily accompany the population and market increases arising from the utilization of the available resources.

The lands along the south shore of Suisun Bay and San Joaquin River from Crockett to the eastern edge of the water district boundary are extremely favorable for industrial location. Many large industries are presently located there and further growth is continuing. Approximately 15,000 acres of land are presently zoned as industrial, and only 5,000, roughly, are now developed. Urban areas to provide homes and service facilities for

the workers are developing in proportion to the industrial growth. Transcontinental railway lines and branches of regional railroads traverse the water district and therefore readily serve industry along the shoreline. Navigable rivers and ocean transportation also facilitate movement of products. Four major State highways serve the county. A tunnel through the Berkeley Hills provides another close link between the water district and the metropolitan bay area. The close proximity of this market and the readily available ocean and railroad transportation facilities for national and international distribution of goods are more than adequate for the district and therefore will encourage the economic growth of the area.

Another factor that will have an increasing effect on the economy of the study area is the increase in developed recreational areas. The available recreation facilities are extensively used at present and the use will continue to increase as the area develops.

Future Growth: The major stimulus for economic growth in the study area is an abundance of subsidiary resources and market factors that can be expected to be used in the development process. The State of California and the west coast is an expanding market for consumer goods and the favorable climate attracts "footloose" industries. The available labor supply, developed transportation system and relative availability of industrial land put the eastern Contra Costa County area in a good competitive position to attract industry.

Population expansion is expected to increase, even without an accompanying growth of an industrial base. The availability of land for residential housing and the improved access to the area from the greater metropolitan area are two factors which stimulate a growth in residential housing.

The conversion of agricultural land and improvement of nonagricultural lands will continue to provide a supply of land for residential and industrial use.

Development will generally follow the existing pattern, growing primarily along the transportation arteries and gradually diffusing to the interior of the county.

The specific figures of the future growth of this area are covered in the Commerce Department report and will not be repeated here.

Estimate of Future Population: The population projections for the Contra Costa County Water District Service Area are shown in Figure 1. This service area includes the present territory of the District plus the contiguous developable land not within other water districts. This is the land area that could ultimately be served through the facilities of Contra Costa Canal and would thereby receive the benefit of any water quality improvement. The benefits accruing to any expansion of service area were not investigated. Benefits will undoubtedly exist but the measurement of them was beyond the scope of this study. These figures are based on the Department of Commerce figures of Contra Costa County growth.

Because of economics, population and land-use, projections can be only general approximations of future development, and because such projections become less reliable for later decades, this report should be interpreted as a general guide to the future, and its projections should be seen as subject to change with the passage of time and in light of new experience.

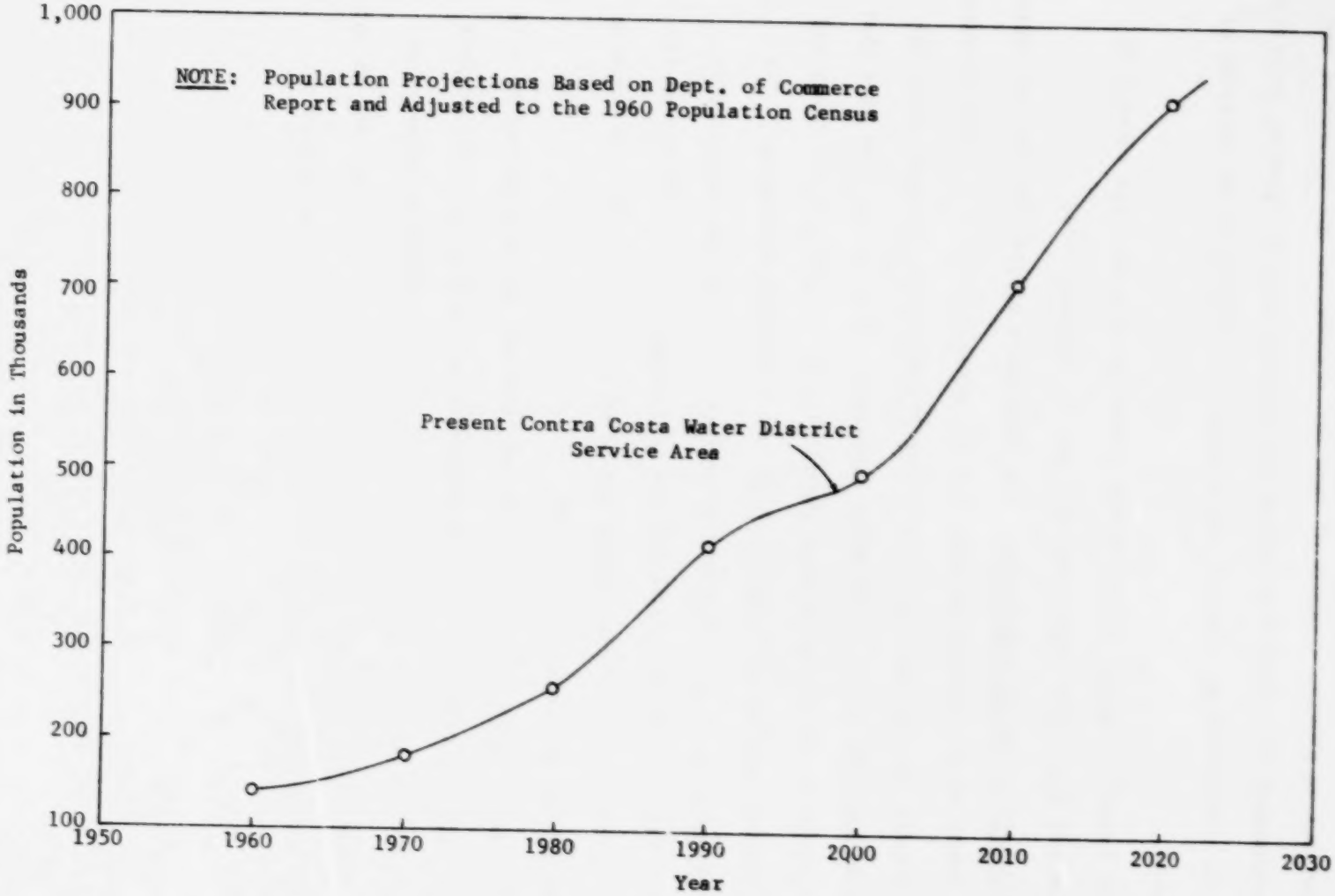


FIGURE-1 POPULATION PROJECTIONS

VII. WATER QUALITY STANDARDS

The quality of water depends upon its origin and history. Natural waters show, in general, qualities broadly characteristic of their sources. Many factors, however, produce variations in the quality of waters obtained from the same type of source. These variations derive from the opportunities for water to take substances into solutions or to carry them in suspension. Climatic, geographic, and geologic conditions all play important parts in determining water quality.

The characteristics of a water which entitle it to the designation of "good quality" are directly dependent upon the use to which the water is to be put. Whatever its other characteristics, a warm, corrosive water would be "of poor quality" for use in condensing steam and a turbid water would be unacceptable for paper manufacture, etc. As for human consumption, regardless of its clarity or turbidity, its hardness or softness, no water that is polluted or exposed to pollution can be considered "of good quality." Thus, it is now generally accepted that a public water supply used for domestic as well as general industrial purposes should be clean, pleasant to taste, of reasonable temperature, neither corrosive nor scale-forming, free of minerals which would produce undesirable physiological effects, and free from disease-producing organisms.

Since the quality of public water supplies is based primarily on satisfying the general requirements of the public, with primary consideration given to potability, the special demands of many industries cannot be met by public supplies. Special water supply requirements of individual industries are so varied that they cannot be covered in this brief text. It is obvious that a water suited for one industry will not be satisfactory for another industry. In most respects, however, the water supply requirements of

industries are consistent with the general demands of the public for a clear, attractive water of moderate mineral content, free from iron and manganese.

Standards for Quality

In order to judge the quality of any product, it is necessary to have some standard. In 1914, the U.S. Public Health Service developed standards for water used on interstate carriers.

The U.S. Public Health Service standards aimed at what was thought to be the major danger in water supplies. The standards had three major kinds of requirements: (1) bacteriologic, (2) physical, and (3) chemical.

The bacteriologic standard specified a maximum coliform organism content and a maximum total bacterial content. The physical standard placed limits on such things as taste, odor, and turbidity of a supply. The chemical standard limited the concentration of certain chemicals that were known or thought to be detrimental, such as arsenic, iron, zinc, and copper.

The Drinking Water Standards should not, however, be considered as the final authority in judging the quality of a water. The recommended limits expressed are used to indicate the levels at which the water is made objectionable to an appreciable number of people and users. The objective is not to establish standards of purity, but rather limits of impurities so that water supplies will be free from injurious effects upon the human body.

There have been many changes in the U.S. Public Health Service Drinking Water Standards, the latest being in 1962. A summary of the latest revisions is shown in Table 5.

In general, "grounds for rejection" limits are based on the fact that the substances enumerated represent hazards to the health of man. In arriving at specific limits, the total environmental exposure of man to a stated

TABLE 5

SUMMARY OF A PORTION OF U.S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS
Federal Register, March 6, 1962

A. Physical Characteristics

Item	Limit
Turbidity	5 Units
Color	15 Units
Threshold Odor Number	3

B. Chemical Characteristics (excluding radioactivity and fluoride)

Substance	Concentration in mg/l*
Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (As)	0.01
Chloride (Cl)	250
Copper (Cu)	1.0
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3) 1/	45
Phenols	0.001
Sulfate (SO_4)	250
Total Dissolved Solids	500
Zine (Zn)	5

Substance	Concentration in mg/l**
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

1/ In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

* These substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the reporting agency and the certifying authority, other more suitable supplies are or can be made available.

** The presence of these substances in excess of the concentrations listed shall constitute grounds for rejection of the supply.

specific toxicant has been considered. An attempt was made to set limits at the lowest practical level in order to minimize the amount of a toxicant contributed by water, particularly when other sources such as milk, food, and air are known to represent the major exposure of man.

The limits which should not be exceeded when more suitable supplies can be made available are based on factors which render a supply less desirable for use. These considerations relate to materials which impart objectionable taste and odor to water, render it economically or aesthetically inferior, or are toxic to fish and plants.

In terms of broad general interest and significance, the most important chemical characteristics of a water supply are those of hardness and total mineral content or salinity. Hardness is primarily due to the presence of calcium and magnesium, either of which may occur in one or more forms.

As is commonly known, hard water is a detriment to many household operations, bringing about excessive use of soap, and heat, and other losses by scale formulation in hot water heaters. In industry, hard water is a detriment to numerous operations and in an economic sense is a factor of considerable magnitude. To avoid losses resulting from scale formation in steam boilers and in heat exchange equipment, large sums are frequently spent for water softening facilities capable of producing a water of either low or zero hardness. These investments pay for themselves and are more than justified by the resulting savings in operation and maintenance.

Salinity, as measured by chloride content and total dissolved solids, is also significant to both domestic and industrial users. It is recommended that there be no more than 250 ppm chlorides and no more than 500 ppm total dissolved solids in water for these uses when supplies of such water are or

can be available. Concentrations above this level may impart a salty or brackish taste although some people can detect a salty taste at an ion concentration of 100 ppm.

Salinity is particularly significant in industrial operations as steam production and water cooling. In operations of this type, a high salinity concentration necessitates a high rate of blowdown to keep concentrations at a safe level and affects the cost of water accordingly. It is evident, therefore, that both hardness and salinity may, in an economic sense, have a very substantial impact on the use of water for domestic and industrial purposes.

Because of the importance of salinity and hardness in a water supply, a great deal of consideration should be given to developing a supply that will result in as low concentrations as feasible of these two items. They should in no way restrain the economic development of an area. Also, they should not create an economic burden on the municipal and industrial water users in the area. A water supply should be developed to serve the people and not vice versa.

There is a broad area of aesthetic value which must be considered in a water supply system. Although this value cannot be readily measured, it will be reflected in the satisfaction to the user.

VIII. PROJECTED WATER DEMAND

Past and Present Water Use

The following table shows the total annual water sales by the Contra Costa County Water District (C.C.C.W.D.) for the period 1950-1961. Future water requirements were extrapolated from these figures by procedures generally described below.

TABLE 6

HISTORIC ANNUAL WATER SALES
Contra Costa County Water District Service Area
(Acre-feet)*

Year	Municipal Use	Industrial Use	Agricultural Use	Total Use
1950	10,832	8,545	4,643	24,040
1951	10,957	9,710	6,515	27,182
1952	11,950	9,812	3,520	25,282
1953	12,035	15,675	4,335	32,045
1954	16,192	15,608	6,327	38,127
1955	20,218	18,844	6,283	45,345
1956	16,681	19,716	5,057	41,454
1957	20,395	24,020	5,752	50,167
1958	17,410	25,609	3,744	46,763
1959	25,686	32,628	5,968	64,282
1960	24,200	39,832	5,309	69,341
1961	25,736	41,023	7,291	74,050

*Figures to nearest acre-foot.

Quantity of Water

Future Municipal Water Requirements. From data supplied by the Contra Costa County Water District, the total water consumption in 1960 by municipal customers was 24,199.95 acre-feet. A summary of independent reports of water production for eight water treatment facilities in the service area indicated a municipal delivery of 21,306 acre-feet per year. The difference between the two figures represents the approximate quantity of treated municipal

water delivered to major industries. The latter figure was used as a base for total water use extensions beyond 1960.

From water delivery and population figures, the per capita consumption in 1960 was computed to be approximately 135 gallons per day. Many authorities agree that the per capita consumption of municipal water will increase with time. Estimates in the California Water Plan, for example, indicate an expected per capita consumption rate of 200 gallons per day in the year 2020. In recognition of the fact that industrial water uses are being excluded in this analysis and with cognizance of the socio-economic character of the service area, it is believed that a value of 200 gallons per capita per day is somewhat excessive. For the analysis presented herein, an average consumer use in the year 2020 is predicted at 155 gallons per capita per day. Using this range of per capita consumption and the population estimates as previously described, the total water delivery for municipal purposes was estimated. Table 7 summarizes estimated municipal water use for the Contra Costa County Water District Service Area for the period 1960 to 2020.

TABLE 7

POPULATION GROWTH, PER CAPITA USE,
AND TOTAL MUNICIPAL WATER USE
Contra Costa County Water District Service Area
1960-2020

Year	Population Persons	Per Capita Use Gallons/day	Total Water Use MG/day	Total Water Use AF/year
1960	141,000	135	19.04	21,306
1970	179,000	140	25.1	28,080
1980	255,000	144	36.7	41,150
1990	421,000	148	62.3	70,050
2000	491,000	151	74.1	83,080
2010	708,000	153	108.3	121,770
2020	918,000	155	142.3	159,440

Future Industrial Water Requirements. The term "industrial water requirement" as used in this report is the water needed by industries having large requirements, such as chemical plants, petroleum refineries, steel mills, and paper mills. Such water requirements may or may not be supplied from municipal systems. For the purposes of this report, the essential distinction is that industrial water use is not directly related to the population of the area.

The future industrial water requirement projection was based upon the present water use per acre of developed industrial land. This unit water use was then correlated with the anticipated development of available industrial land. The following table summarizes the future industrial water requirements using this projection method.

TABLE 8

PROJECTED INDUSTRIAL WATER REQUIREMENTS
Contra Costa County Water District Service Area

Year	Total Water Use AF/year
1960	42,726*
1970	75,900
1980	111,800
1990	147,700
2000	183,600
2010	219,500
2020	255,000

*Actual figure to nearest acre-foot

Another projection of the total industrial water requirement to be supplied by the Contra Costa Canal is the projection for that part of the Delta area lying in Contra Costa County as presented in the California Department of Water Resources Bulletin No. 76, "Delta Water Facilities." The "Delta Water Requirement" appendix to this bulletin contains detailed explanations

of how the requirements were projected. The Contra Costa Canal projection assumes that the industrial water requirement in the Contra Costa County Water District service area will be in direct proportion to the corresponding requirement as given in Bulletin No. 76, with the ratio of actual 1960 industrial water sales by the Contra Costa County Water District to the 1960 Bulletin No. 76 value serving as the basis of proportionality. The following table presents these projections.

TABLE 9

PROJECTED INDUSTRIAL WATER REQUIREMENTS
Contra Costa County Water District Service Area
Based on Bulletin No. 76

Year	Total Water Use AF/year
1960	42,726*
1970	89,000
1980	148,000
1990	218,000
2000	296,000
2010	384,000
2020	477,000

*Actual figure to nearest acre-foot.

For the purposes of this report, the more conservative projections as shown in Table 8 are used for the calculations of benefits accrued by industry due to the improvement of water quality.

Future Irrigated Agriculture Water Requirements. Due to the rapid trend toward urban type expansion that is expected to take place in the Contra Costa County Water District, agriculture is expected to be relegated to a minor position as more and more potential agricultural lands are taken over by the expansion of urban, suburban, and industrial developments. It is expected that the total acreage devoted to agriculture will increase in the future but

the competition for residential land will definitely limit this growth. However, it might also be expected that farming methods will become more intensive, and that water use per acre will be increased. Based upon these two assumptions, the total water use by irrigated agriculture is projected to increase from 5,309 acre-feet at present to 24,000 acre-feet in 60 years. The following table presents the decade projections of agricultural water use.

TABLE 10

PROJECTED IRRIGATED AGRICULTURE WATER REQUIREMENTS
Contra Costa County Water District Service Area

Year	Total Water Use AF/year
1960	5,309*
1970	9,000
1980	12,000
1990	15,000
2000	18,000
2010	21,000
2020	24,000

*Actual figure to nearest acre-foot.

Total Projected Water Requirements. The following table summarizes the total projected water requirements for the Contra Costa County Water District Service Area for the period 1960 to 2020.

TABLE 11

TOTAL PROJECTED WATER REQUIREMENTS
Contra Costa County Water District Service Area
1960-2020
(Acre-feet per year)

Year	Municipal	Industrial	Agriculture	Total
1960	21,306*	42,726*	5,309*	69,341*
1970	28,080	75,900	9,000	112,980
1980	41,150	111,800	12,000	164,950
1990	70,050	147,700	15,000	232,750
2000	83,080	183,600	18,000	284,680
2010	121,770	219,500	21,000	362,270
2020	159,440	255,000	24,000	438,440

*Actual figures to nearest acre-foot.

Quality of Water

Present Water Quality Characteristics. The three conditions that are the major cause of the degradation of water quality at the Contra Costa Canal intake are as follows: decreasing flows in the tributary streams to the Delta, increasing municipal and industrial waste discharges to these tributary streams and increasing irrigation return flows to the tributary streams and to the Delta channels. These conditions reached a peak during the dry years of 1959-61. It is felt that this 1959-61 period represents conditions at their extreme as this was a dry period with upstream water use at a maximum. Also, 1959 was the first year that all major flows into the Delta area were controlled. Conditions are not expected to exceed these and for this reason the 1959-61 period will be used as the historic period for this investigation.

It has been assumed that the maximum benefits to be derived from the Kellogg project will result from the control of chloride concentration and total hardness. Based on discussions with Bureau of Reclamation and Contra Costa County Water District officials, representatives of industries, and technical consultants, as well as Public Health Service experience, industrial benefits were related directly to a reduction in chlorides to a desirable and achievable level of 100 ppm. Major municipal benefits are derived from the reduction in total hardness of the project waters.

Figure 2 summarizes the historic chlorides in the Contra Costa Canal. A closely comparable curve representing the 1961 chloride concentrations in the Contra Costa Canal also is shown. This latter year is the only period for which industrial cost data associated with water quality were acquired.

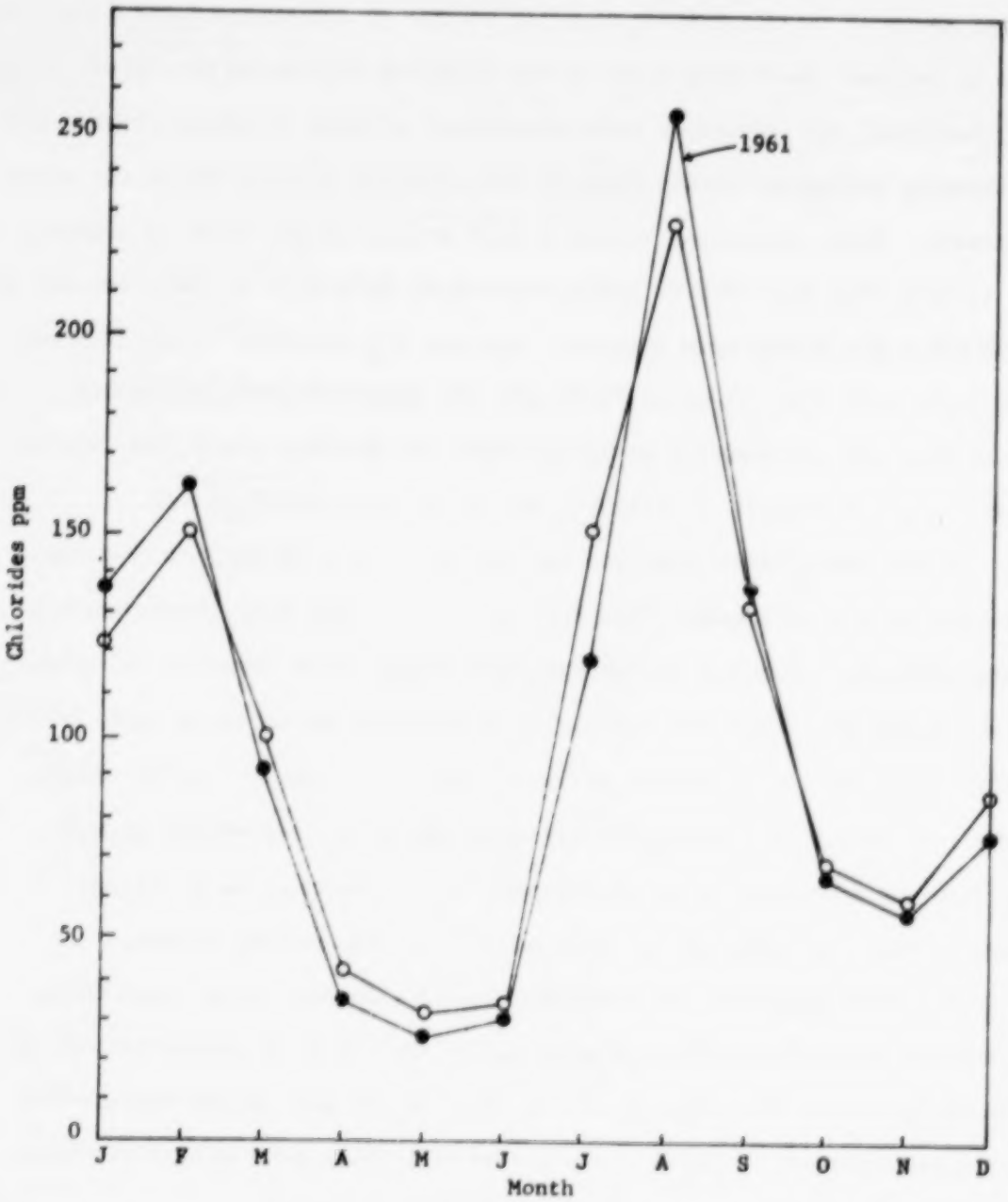


FIGURE-2 CHLORIDES - CONTRA COSTA CANAL
1959-1961 AVERAGE

Figure 3 summarizes the total hardness in the Contra Costa Canal at the head-end. Usually, the seasonal pattern of hardness as shown in the figure possesses two typical peaks; one occurring in January or February of each year, and another in July, August and September of the year. From the first peak, which is the higher of the two, the total hardness declines rapidly, reaching a minimum in the months of May and June. During the period of salinity intrusion into the Delta (note Figure 2), hardness again increases and is associated primarily with increases in chlorides.

As might be expected, the pattern of chloride concentration and hardness exhibited in the Delta-Mendota Canal waters, as shown in Figures 4 and 5, respectively, reflect the hydrologic characteristics of the Sierra streams. That is, the water of the poorest quality occurs during the period from January through March when the surface runoff and higher stream flows flush accumulated salts, minerals and sediments from upstream areas into the Delta; and during the months of July, August and September when upstream water demands decrease the fresh water flow, thereby allowing saline waters to intrude into the Delta region.

Department of Health, Education, and Welfare, Public Health Service Sampling Program. The Department of Health, Education, and Welfare, Public Health Service, operated a sampling program to study the actual quality characteristics of the Contra Costa and Delta-Mendota Canals waters for the period of the Kellogg investigation study. Identical sampling stations were located at the head-end of the Contra Costa Canal and the Delta-Mendota Canal. Samples were taken at these locations for determination of radioactivity, organic chemicals, and plankton populations. Chemical analyses were also made on samples to detect concentrations of the following: bicarbonates, sulfates, chlorides, total dissolved solids, ammonia nitrogen, beryllium,

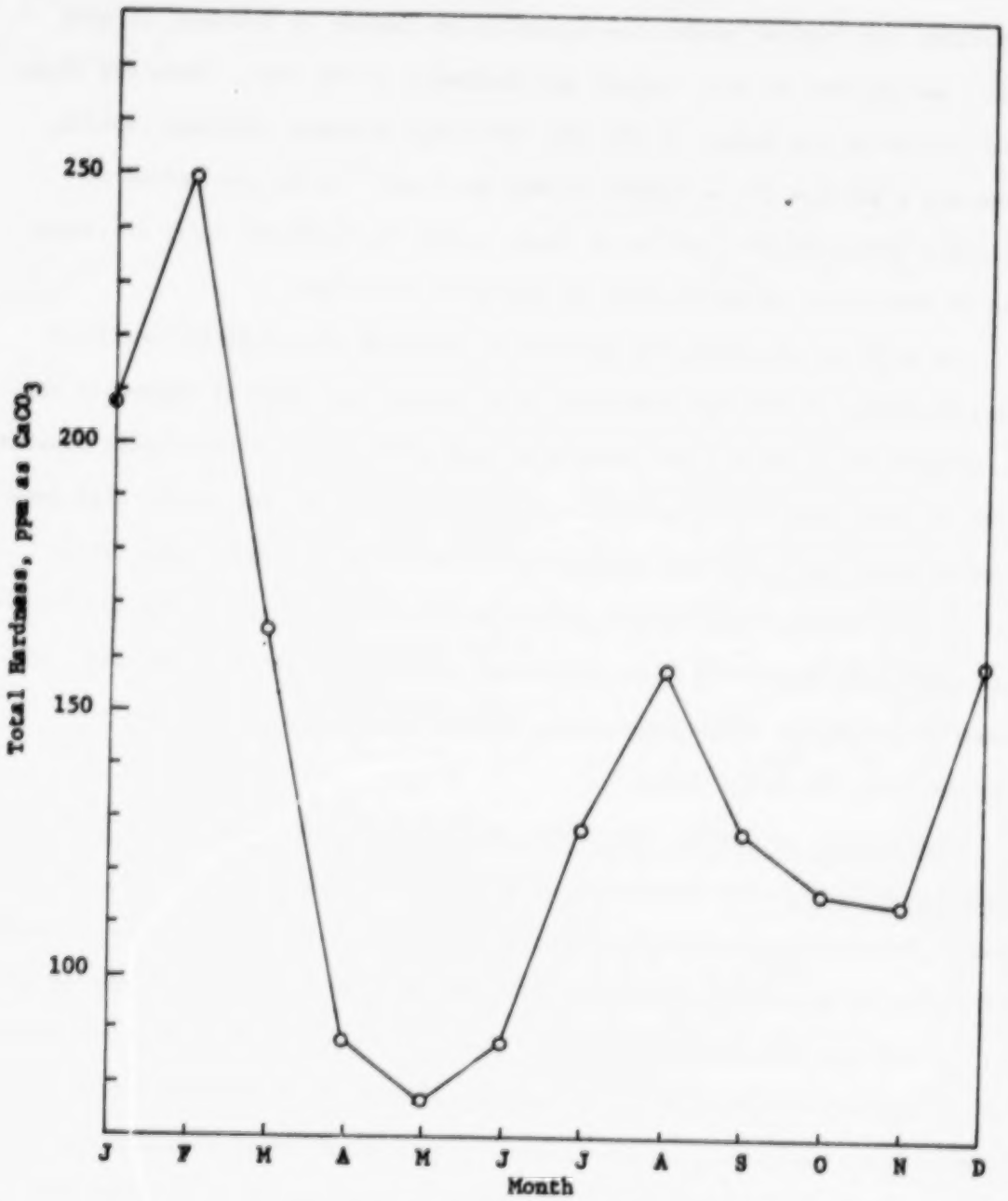


FIGURE-3 TOTAL HARDNESS-CONTRA COSTA CANAL
1959-1961 AVERAGE

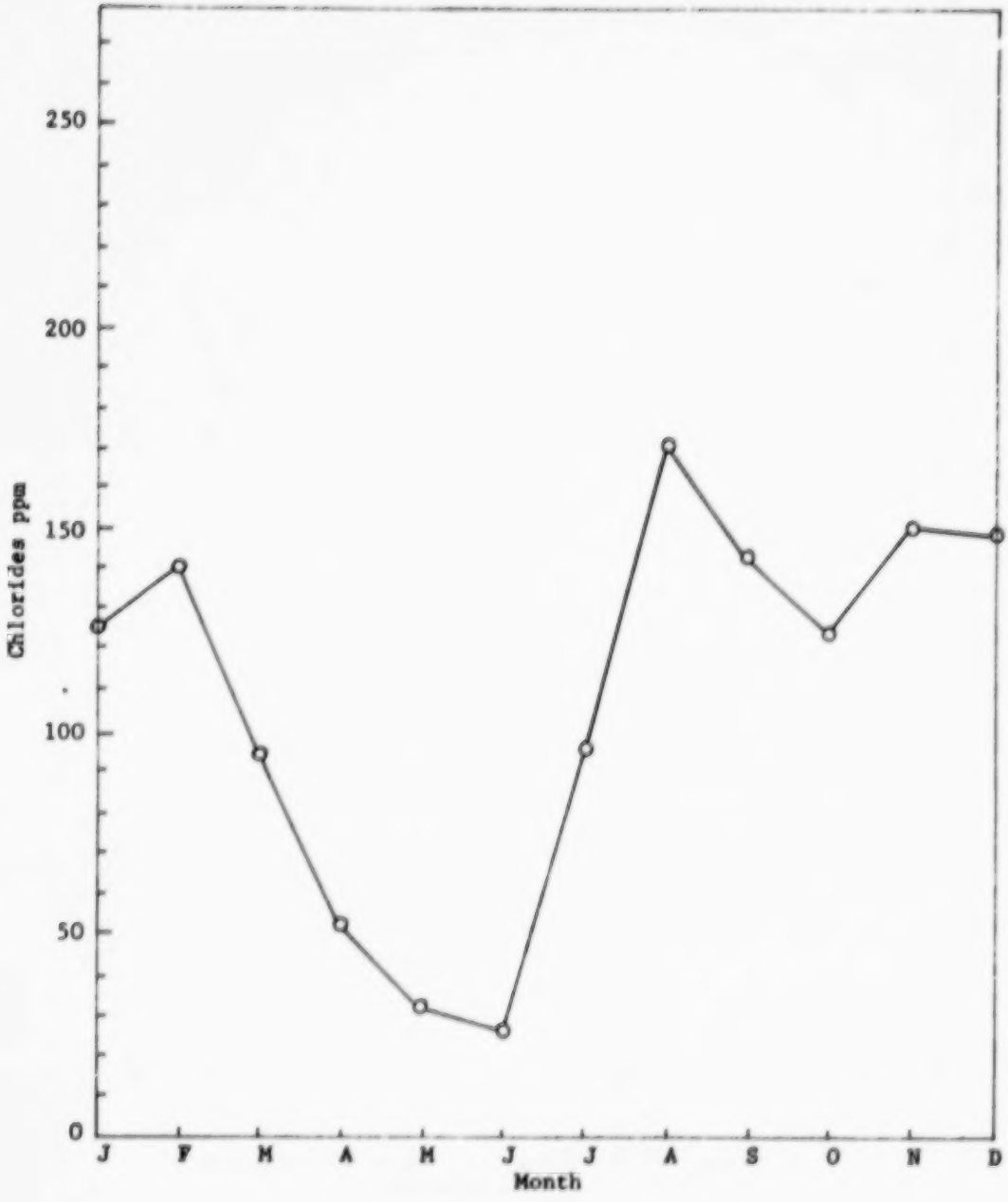


FIGURE-4 CHLORIDES - DELTA MENDOTA CANAL
1959-1961 AVERAGE

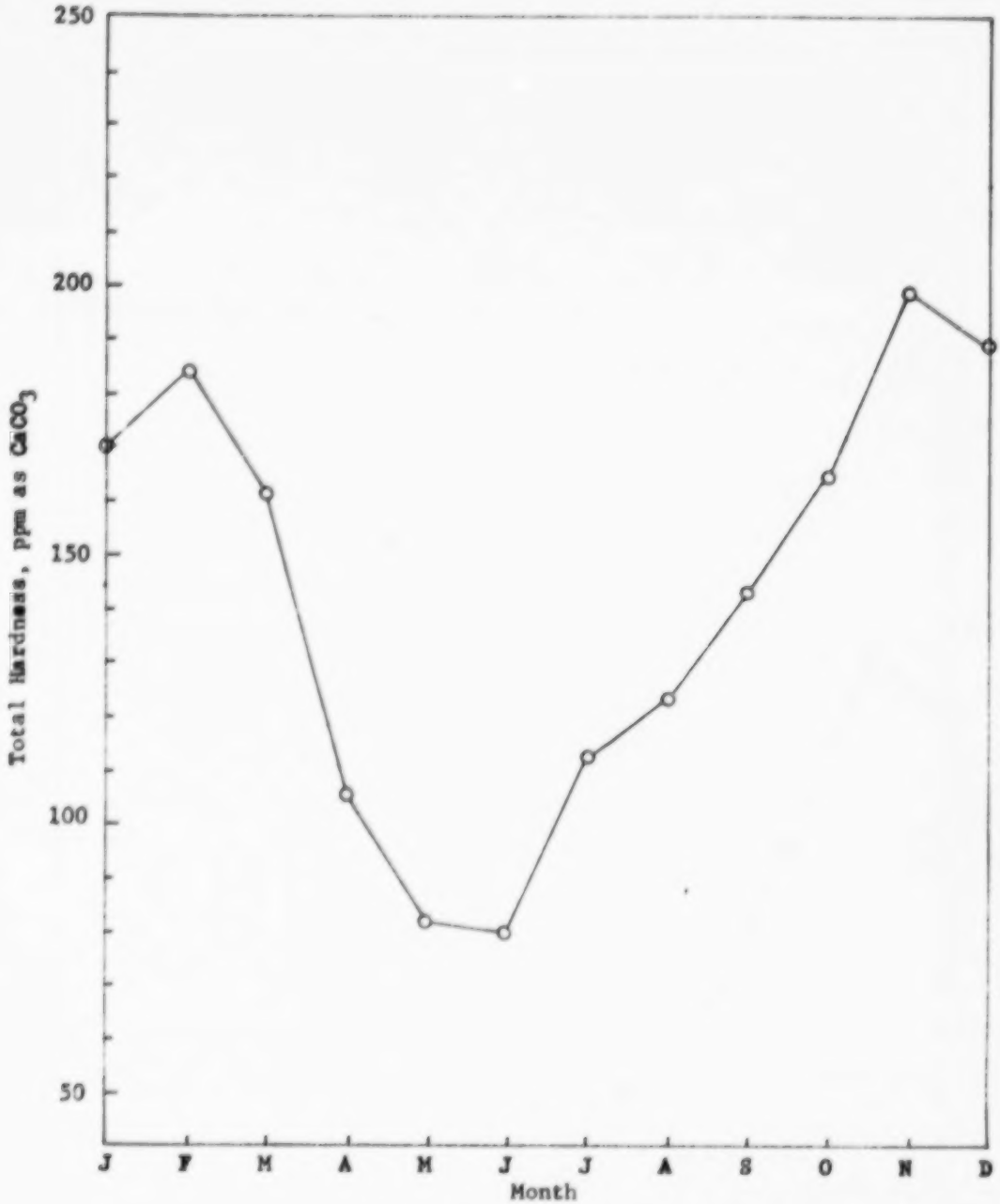


FIGURE-5 TOTAL HARDNESS - DELTA MENDOTA CANAL
1959-1961 AVERAGE

tin, vanadium, phosphates, alkyl benzene sulfonate, calcium, magnesium, sodium, potassium, boron, arsenic, copper, fluoride, iron, manganese, zinc, barium, cadmium, chromium, lead, nickel, selenium, and silver. The primary interest in operating the sampling program was to study any variations in the quality characteristics of the canals waters from the Public Health Service Drinking Water Standards and to observe any irregularities.

The results of the sampling program are shown in Tables 12 and 13.

In general, the analytical results showed that the canal waters were within the recommended limits of the Public Health Service Drinking Water Standards (see Table 5). The constituents not covered in the Standards were compared to limits of concentrations discussed in the publication "Water Quality Criteria" (23).

Referring to Tables 12 and 13, the underlined concentrations are those that exceed these two accepted guides. The constituents found to be in excess were boron, chromium, iron, nickel, and manganese. In order to determine the sources and frequency of occurrence of these high concentrations, a longer and more detailed sampling program than was used in this investigation would be necessary. It is possible, however, to indicate generally the possible origin and effects of these metals.

Boron occurs naturally in the form of borax, borates, boric acid, and various borosilicates. It can be found also in fertilizers and certain industrial waste waters, such as those from citrus washing. In concentrations of less than 30 ppm, boron in drinking water is not considered hazardous to human beings. Traces of boron are necessary for satisfactory plant growth but concentrations of the element only slightly higher than those needed for optimum growth may be toxic. Concentrations of boron in

TABLE 12

RESULTS* OF THE DHEW-PHS SAMPLING PROGRAM - CONTRA COSTA CANAL

Date	Alkyl Benzene Sulfonate	Chloride	Sulfate	Total Dissolved Solids	Ammonia Nitrogen	Phosphate	Bicarbonate	Carbon Column Extract		Antimony	Arsenic	Barium
1962	ABS	Cl	SO_4	TDS	$NH_{3/N}$	PO_4	HCO_3	Alco-nol	Chloro-form	Sb	As	Ba
3/16	0.22	111	130	471	0.14	0.27	82	127	40	0.05	0.01	0.02
3/26	0.13	78	80	358	0.00	0.15	88					
4/2	0.06	80	75	325	0.25	0.25	84	89	49	0.02	0.01	0.05
4/6												
4/13	0.07	61	70	312	0.26	0.02	76					
4/20	0.07	42	50	250	0.36	0.07	70	100	56			
4/27	0.06	35	38	229	0.17	0.03	61			0.02	0.01	0.02
5/7								70	13			
5/11	0.08	20	18	143	0.17	0.20	52			0.01	0.01	0.007
5/18	0.02	23	23	160	0.15	0.48	50	80	52			
5/25	0.08	25	23	141	0.15	0.05	54			0.02	0.01	0.003
6/1	0.06	29	29	158	0.14	0.10	59	56	54			
6/8	0.05	23	27	159	0.08	0.15	58			0.02	0.01	0.01
6/15	0.04	23	29	131	0.14	0.05	62	72	44			
6/22												
6/29	0.04	45	24	140	0.20	0.02	62	74	41			

*All results as mg/l except carbon column extract which is expressed as parts per billion.

TABLE 12 (Continued)

RESULTS* OF THE DHEW-PHS SAMPLING PROGRAM - CONTRA COSTA CANAL

Date	Beryllium	Bismuth	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Fluoride	Iron	Lead
1962	Be	Bi	B	Cd	Ca	Cr	Co	Cu	F	Fe	Pb
3/16	0.0002	0.02	0.66	0.01	38	0.005	0.009	0.04	0.29	0.03	0.02
3/26											
4/2	0.0001	0.01	0.47	0.007	30	0.1	0.004	0.02	0.00	2.25	0.01
4/6											
4/13											
4/20											
4/27	0.001	0.01	0.17	0.007	20	0.002	0.004	0.02	0.13	0.2	0.01
5/7											
5/11	0.0007	0.007	0.10	0.004	12	0.001	0.003	0.1	0.27	0.1	0.007
5/18											
5/25	0.0008	0.008	0.08	0.005	12	0.002	0.003	0.2	0.27	0.01	0.03
6/1											
6/8	0.0008	0.008	0.12	0.005	14	0.002	0.003	0.003	0.34	0.005	0.008
6/15											
6/22											
6/29											

*All results as mg/l except carbon column extract which is expressed as parts per billion.

TABLE 12 (Continued)

RESULTS* OF THE DHEW-PHS SAMPLING PROGRAM - CONTRA COSTA CANAL

Date	Magnesium	Manganese	Molybdenium	Nickel	Potassium	Selenium	Silver	Sodium	Tin	Vanadium	Zinc
1962	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sn	V	Zn
3/16	26	0.02	0.01	0.04	2.0	0.01	0.0002	99	0.009	0.009	2.0
3/26											
4/2	18	0.009	0.002	0.004	2.8	0.01	0.0001	66	0.04	0.01	1.0
4/6											
4/13											
4/20											
4/27	16	0.009	0.002	0.2	2.3	0.01	0.0001	29	0.004	0.01	1.0
5/7											
5/11	8.0	0.006	0.003	0.07	2.0	0.01	0.006	16	0.003	0.003	0.7
5/18											
5/25	8.3	0.006	0.003	0.2	1.9	0.01	0.0006	16	0.003	0.003	0.8
6/1											
6/8	10	0.006	0.003	0.003	1.6	0.01	0.0008	20	0.003	0.003	0.8
6/15											
6/22											
6/29											

*All results as mg/l except carbon column extract which is expressed as parts per billion.

TABLE 13

RESULTS* OF DHEW-PHS SAMPLING PROGRAM - DELTA-MENDOTA CANAL

Date	Alkyl Benzene Sulfonate	Chloride	Sulfate	Total Dissolved Solids	Ammonia Nitrogen	Phosphate	Bicarbonate	Carbon Column Extract		Antimony	Arsenic	Barium
1962	ABS	Cl	SO_4	TDS	$NH_{3/N}$	PO_4	HCO_3	Alcohol	Chloroform	Sb	As	Ba
4/6								372	166			
4/13	0.06	95	83	397	0.26	0.2	84					
4/20	0.2	55	55	264	0.39	0.03	66	331	89			
4/27	0.09	62	48	261	0.15	0.55	71			0.02	0.01	0.08
5/7	0.12	63	50	299	0.5	0.00	70					
5/11	0.08	45	28	194	0.12	0.25	58	166	53	0.02	0.01	0.01
5/18	0.04	32	25	172	0.17	0.25	52					
5/25	0.08	37	25	191	0.20	0.10	62	74	51	0.02	0.01	0.02
6/1	0.11	38	32	155	0.13	0.03	59	58	57			
6/8	0.03	40	31	188	0.27	0.03	68			0.02	0.01	0.004
6/15	0.05	30	27	138	0.15	0.1	52	91	49			
6/22												
6/29	0.27	61	27	157	0.25	0.28	58	80	47			

*All results as mg/l except carbon column extract which is expressed as parts per billion.

TABLE 13 (Continued)

RESULTS* OF DHEW-PHS SAMPLING PROGRAM - DELTA-MENDOTA CANAL

Date	Beryllium	Bismuth	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Fluoride	Iron	Lead
1962	Be	Bi	B	Cd	Ca	Cr	Co	Cu	F	Fe	Pb
4/6											
4/13											
4/20											
4/27	0.0001	0.01	0.17	0.005	27	0.002	0.003	0.03	0.18	0.8	0.01
5/7											
5/11	0.0001	0.01	0.14	0.006	17	0.002	0.004	0.2	0.38	0.2	0.02
5/18											
5/25	0.0001	0.009	0.10	0.005	15	0.002	0.003	0.02	0.32	0.05	0.0009
6/1											
6/8	0.0001	0.009	0.10	0.006	20	0.002	0.004	0.009	0.40	0.004	0.009
6/15											
6/22											
6/29											

*All results as mg/l except carbon column extract which is expressed as parts per billion.

TABLE 13 (Continued)

RESULTS* OF DHEW-PHS SAMPLING PROGRAM - DELTA-MENDOTA CANAL

Date	Magnesium	Manganese	Molybdenium	Nickel	Potassium	Selenium	Silver	Sodium	Tin	Vanadium	Zinc
1962	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sn	V	Zn
4/6											
4/13											
4/20											
4/27	18	0.016	0.003	0.8	2.5	0.01	0.03	43	0.016	0.008	0.8
5/7											
5/11	9.2	0.008	0.004	0.02	2.5	0.01	0.002	30	0.004	0.004	1.0
5/18											
5/25	8.5	0.007	0.003	0.07	2.0	0.01	0.003	43	0.003	0.003	0.9
6/1											
6/8	12	0.1	0.004	0.004	2.0	0.01	0.009	25	0.004	0.004	0.9
6/15											
6/22											
6/29											

*All results as mg/l except carbon column extract which is expressed as parts per billion.

water above 2 to 4 ppm may be injurious to most plants, and concentrations in excess of 0.3 may be injurious to sensitive crops, since continuous application at this concentration may cause a concentration in the soil or more than 4 ppm.

At present, chromium is not known to be either an essential or beneficial element in the body. The limit of 0.05 mg/l for chromium as hexavalent chromium ion appearing in the Standards was based on the lowest amount analytically determinable at the time it was established. The presence of chromium at a concentration of 0.1 ppm may be attributable to an industrial waste of some sort.

Both iron and manganese are highly objectionable constituents in water supplies for either domestic or industrial use. The domestic consumer complains of the brownish color which they impart to laundered goods. Iron appreciably affects the taste of beverages. Concentrations of iron over 0.2 - 0.3 ppm begin to have a deleterious effect on industrial water use.

Elemental nickel seldom occurs in nature, but nickel compounds are found in many ores and minerals. As a pure metal it is not a problem in water pollution because it is not affected by, or soluble in, water. It may, however, have a detrimental effect to beneficial uses. No data on the toxicity of nickel to man has been revealed, but the toxicity is believed to be fairly low. The effect of nickel on the growth of plants is very injurious no matter how small the quantity. In the presence of other elements, nickel has caused pitting of plumbing fixtures. The presence of nickel is indicative of an industrial discharge, such as from cooling towers.

The possible detrimental effects of the above elements are not thought to be critical as they would have to be present over an extended period of time in order to have a harmful effect on the water users in the area. To verify this supposition, however, a longer and more detailed sampling program is recommended to determine specifically the origin and frequency of occurrence of these elements.

Projected Water Quality Characteristics. The Bureau of Reclamation has developed two preliminary reservoir operation series for the Kellogg Reservoir. Series F (Table 14) is based on the historic chlorides and Series G (Table 15) is based on projected chlorides. Projected chlorides are the assumed chloride concentrations of the Delta waters when the State of California and San Luis projects are in operation. Series G is assumed to come into effect in the year 1980. The objective of these operation series was to combine water from the Contra Costa Canal diverted from the San Joaquin River and water from Kellogg Reservoir originating from the Delta-Mendota Canal in such a way as to produce reasonably uniform chloride concentrations, at levels acceptable for most domestic or industrial purposes. It is also possible to perform the same operations for estimating the control of total hardness. For reasons of simplicity in these studies, however, the same operation schedules used for chloride regulation were applied to hardness.

Figure 6 shows the total chloride concentration which could be expected in the Contra Costa Canal during the operation of Kellogg Reservoir for the project period from 1968 to 2020. Results of operation Series F-1 and F-2 are compared to the mean chloride concentration of Contra Costa Canal water for the period 1959-1961. Series F-1 corresponds to the 1959 water demand of Contra Costa Canal and Series F-2 corresponds to the 1960 demand.

TABLE 14
KELLOGG RESERVOIR OPERATION STUDY
QUALITY AND SUPPLY FOR CONTRA COSTA CANAL
HISTORIC DELTA-MENDOTA AND CONTRA COSTA CANAL CHLORIDES
(SERIES F)

Year & Month	Contra Costa Canal (350 cfs) Pump.*	Cl.#	Delta-Mendota Canal (500 cfs) Pump.	Cl.	Reservoir Evaporation Loss	End of Month Storage	Reservoir Release Quantity	Cl.	Release to East Contra Costa County	Contra Costa Canal	Contra Costa Canal Supply	Cl.	Total Yield
1959													
Jan.	0	105	0	105	0	92	12	77	4	8	8	77	12
Feb.	0	125	0	100	0	81	11	77	3	8	8	77	11
Mar.	0	120	8	85	0	76	13	78	3	10	10	78	13
Apr.	11	55	24	45	0	96	4	70	4	0	11	55	15
May	15	42	25	48	0	117	4	65	4	0	15	42	19
June	15	45	24	34	1	135	5	60	5	0	15	45	20
July	0	215	3	136	3	113	22	62	6	16	16	62	22
Aug.	0	275	0	230	2	90	21	62	6	15	15	62	21
Sep.	0	108	20	115	1	90	19	72	5	14	14	72	19
Oct.	13	60	25	95	1	110	4	77	4	0	13	60	17
Nov.	11	58	0	146	0	107	3	77	3	0	11	58	14
Dec.	9	80	0	150	0	104	3	77	3	0	9	80	12
Total	74		129		8		121		50	71	145		195
1960													
Jan.	0	125	0	141	0	83	12	53	4	8	8	53	12
Feb.	0	160	0	135	0	72	11	53	3	8	8	53	11
Mar.	0	100	1	110	0	60	13	54	3	10	10	54	13
Apr.	11	43	24	30	0	80	4	47	4	0	11	43	15
May	15	30	25	29	0	101	4	43	4	0	15	30	19
June	15	29	24	26	1	119	5	40	5	0	15	29	20
July	16	80	25	60	3	135	6	43	6	0	16	80	22
Aug.	0	155	23	112	2	135	21	53	6	15	15	53	21
Sep.	0	160	0	166	1	115	19	53	5	14	14	53	19
Oct.	13	83	0	172	1	110	4	53	4	0	13	83	17
Nov.	11	73	0	157	0	107	3	53	3	0	11	73	14
Dec.	0	110	0	150	0	95	12	53	3	9	9	53	12
Total	81		122		8		114		50		145		195

*All quantity figures in terms of 1000 acre-feet (AF).
#All chlorides expressed as parts per million (ppm).

TABLE 15
KELLOGG RESERVOIR OPERATION STUDY
QUALITY AND SUPPLY FOR CONTRA COSTA CANAL
PROJECTED DELTA-MENDOTA AND CONTRA COSTA CANAL CHLORIDES
(SERIES G)

Year & Month	Contra Costa Canal (350 cfs) Pump.*	Cl.#	Delta-Mendota Canal (500 cfs) Pump.	Cl.	Reservoir Evaporation Loss	End of Month Storage	Reservoir Release Quantity	Cl.	Release to East Contra Costa County	Contra Costa Canal	Contra Costa Canal Supply	Cl.	Total Yield
1959													
Jan.	21	40	31	40	0	119	7	60	7	0	21	40	28
Feb.	19	50	22	50	0	135	6	58	5	1	20	50	25
Mar.	22	80	0	80	0	126	9	58	7	2	24	78	31
Apr.	21	60	6	60	0	119	13	58	7	6	27	60	34
May	22	55	31	55	0	130	20	57	9	11	33	56	42
June	21	50	30	50	1	135	24	56	10	14	35	52	45
July	0	145	31	145	3	112	51	73	12	39	39	73	51
Aug.	0	190	27	190	2	90	47	96	12	35	35	96	47
Sep.	0	120	4	120	1	50	43	97	10	33	33	97	43
Oct.	22	80	16	80	1	50	15	93	8	7	29	83	37
Nov.	21	50	30	50	0	70	10	77	7	3	24	53	31
Dec.	20	45	31	45	0	95	6	67	6	0	20	45	26
Total	189		259		8		251		100	151	340		440
1960													
Jan.	21	50	31	50	0	121	7	52	7	0	21	50	28
Feb.	19	55	20	55	0	135	6	52	5	1	20	55	25
Mar.	0	90	0	90	0	104	31	52	7	24	24	52	31
Apr.	21	45	30	45	0	121	13	50	7	6	27	46	34
May	22	45	31	45	0	132	20	49	9	11	33	46	42
June	21	30	28	30	1	135	24	46	10	14	35	36	45
July	22	40	31	40	3	134	29	45	12	17	39	42	51
Aug.	0	115	31	115	2	116	41	58	12	35	35	58	47
Sep.	0	115	18	115	1	90	43	66	10	33	33	66	43
Oct.	0	85	0	85	1	52	37	66	8	29	29	66	37
Nov.	21	45	30	45	0	72	10	58	7	3	24	47	31
Dec.	20	40	31	40	0	97	6	53	6	0	20	40	26
Total	167		281		8		273		100	173	340		440

*All quantity figures in terms of 1000 acre-foot (AF).
#All chlorides expressed as parts per million (ppm).

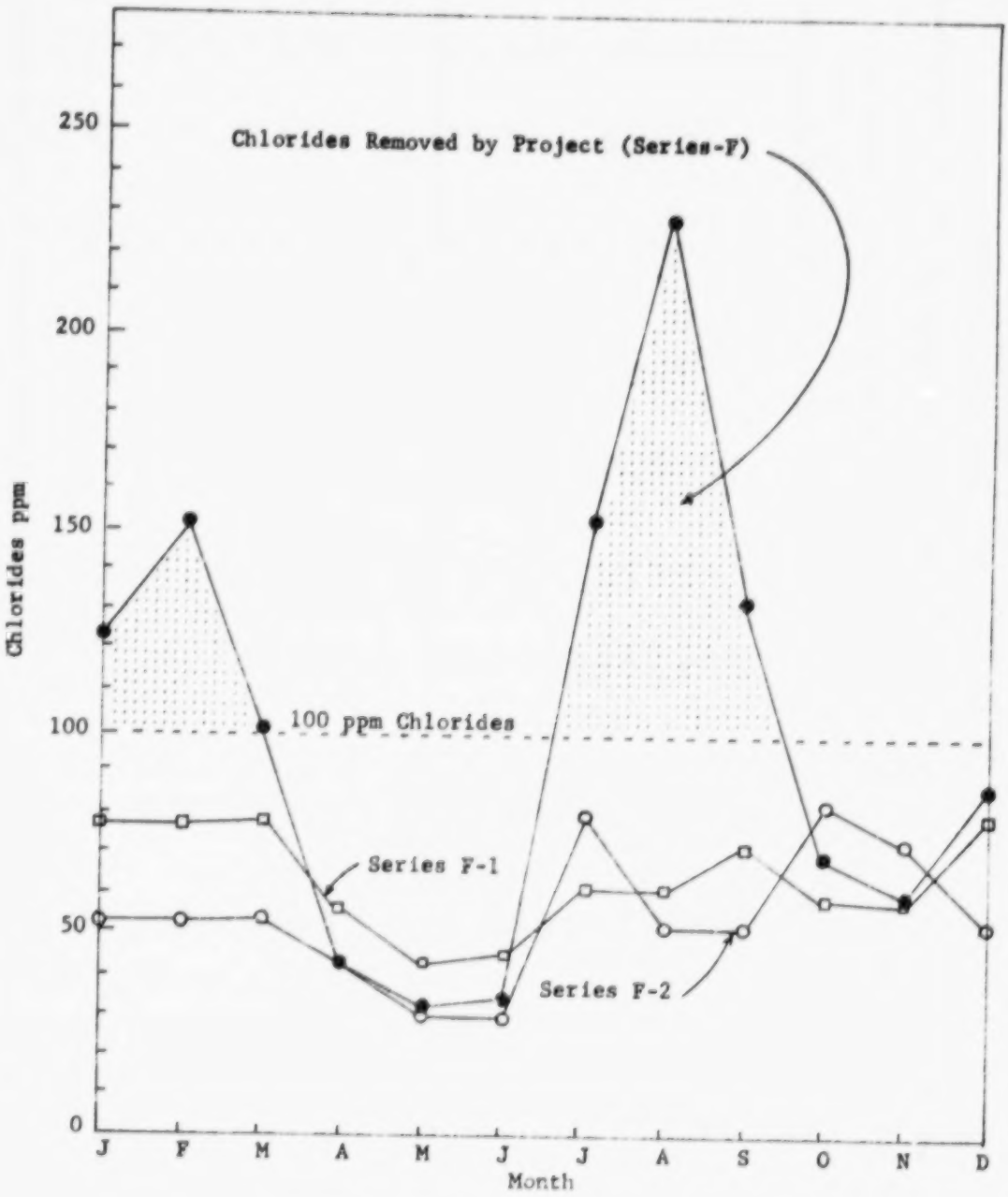


FIGURE-6 CHLORIDES - CONTRA COSTA CANAL
KELLOGG RESERVOIR OPERATION - SERIES-F
1968-2020

The shaded area represents the reduction in chloride concentration upon which the industrial benefits are based.

Figure 7 shows the chloride concentration resulting from the reservoir operation for Series G. Series G is based on the operation of the Kellogg Reservoir in conjunction with the operation of the San Luis Project and the Department of Water Resources Delta Project.

The total hardness which could be expected in the Contra Costa Canal during the operation of Kellogg Reservoir for the project period from 1968 to 2020 is shown in Figure 8. Results of operation Series F-1 and F-2 are compared to the mean hardness of Contra Costa Canal water for the period 1959 to 1961.

Comparison of operation curves for Series F-1 and F-2 with the normal hardness of the Contra Costa Canal water indicates the reduction in hardness (shaded area) which may be expected from the project. Under reservoir operation Series F, the mean hardness delivered to Contra Costa Canal would approximate 102 ppm.

In order to obtain the total hardness of waters delivered through the Contra Costa Canal when the California Department of Water Resources and the San Luis Project are in conjunctive operation with the Kellogg Project, it was necessary to obtain a correlation between hardness and chlorides. This correglation is shown in Figure 9 in which data for the period 1959 through 1961 reveals two distinct correlations, depending upon the season of the year. The steeper line represents the correlation between total hardness and chlorides during the period from September through June and is associated hydrologically with the surface runoff of the streams contributing flow to the Delta. The flatter line represents the correlation between hardness and chlorides for the period July through October and is associated

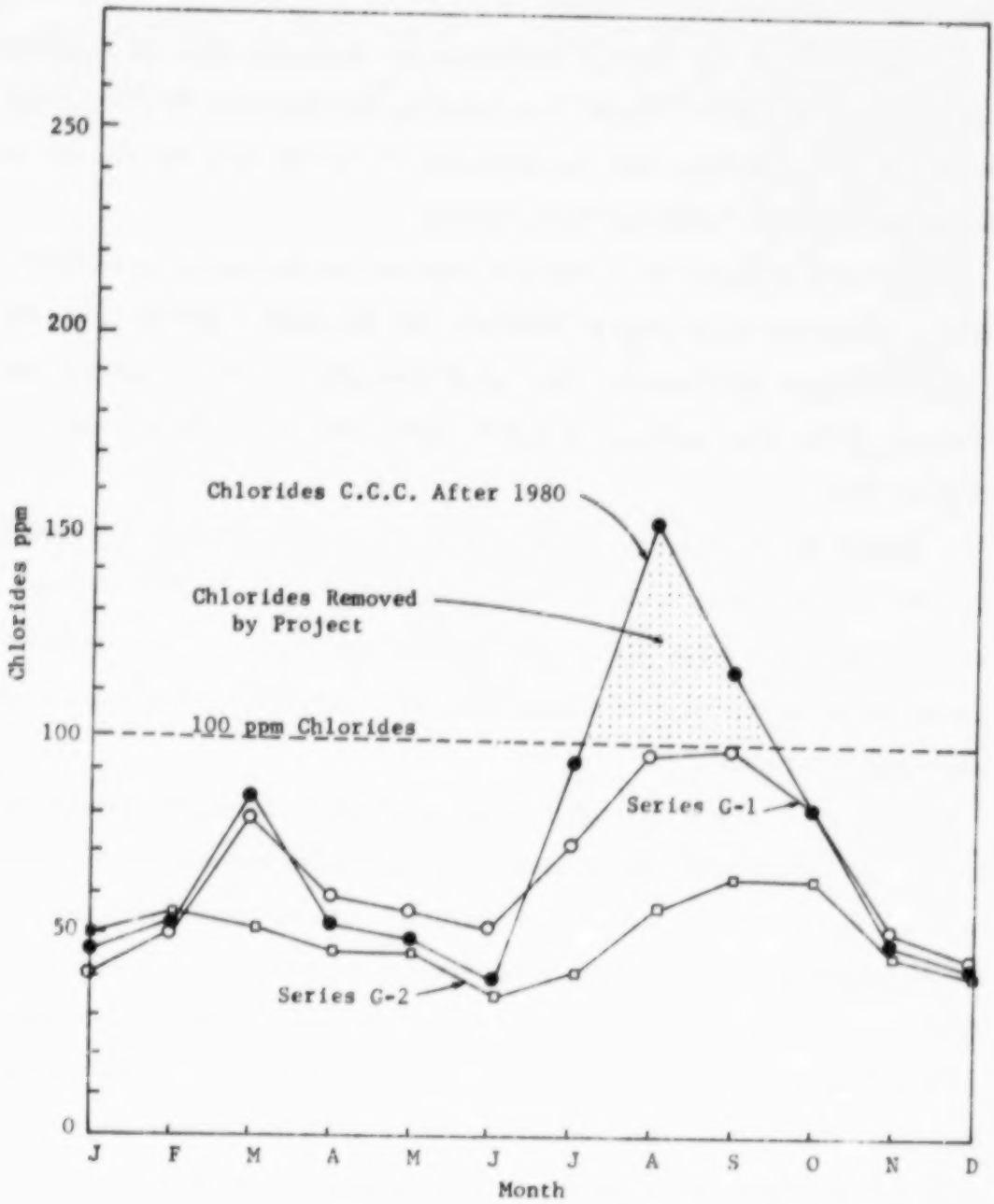


FIGURE-7 CHLORIDES - CONTRA COSTA CANAL
KELLOGG RESERVOIR OPERATION - SERIES-G
1980-2020
BASED ON OPERATION WITH SAN LUIS AND DWR PROJECTS

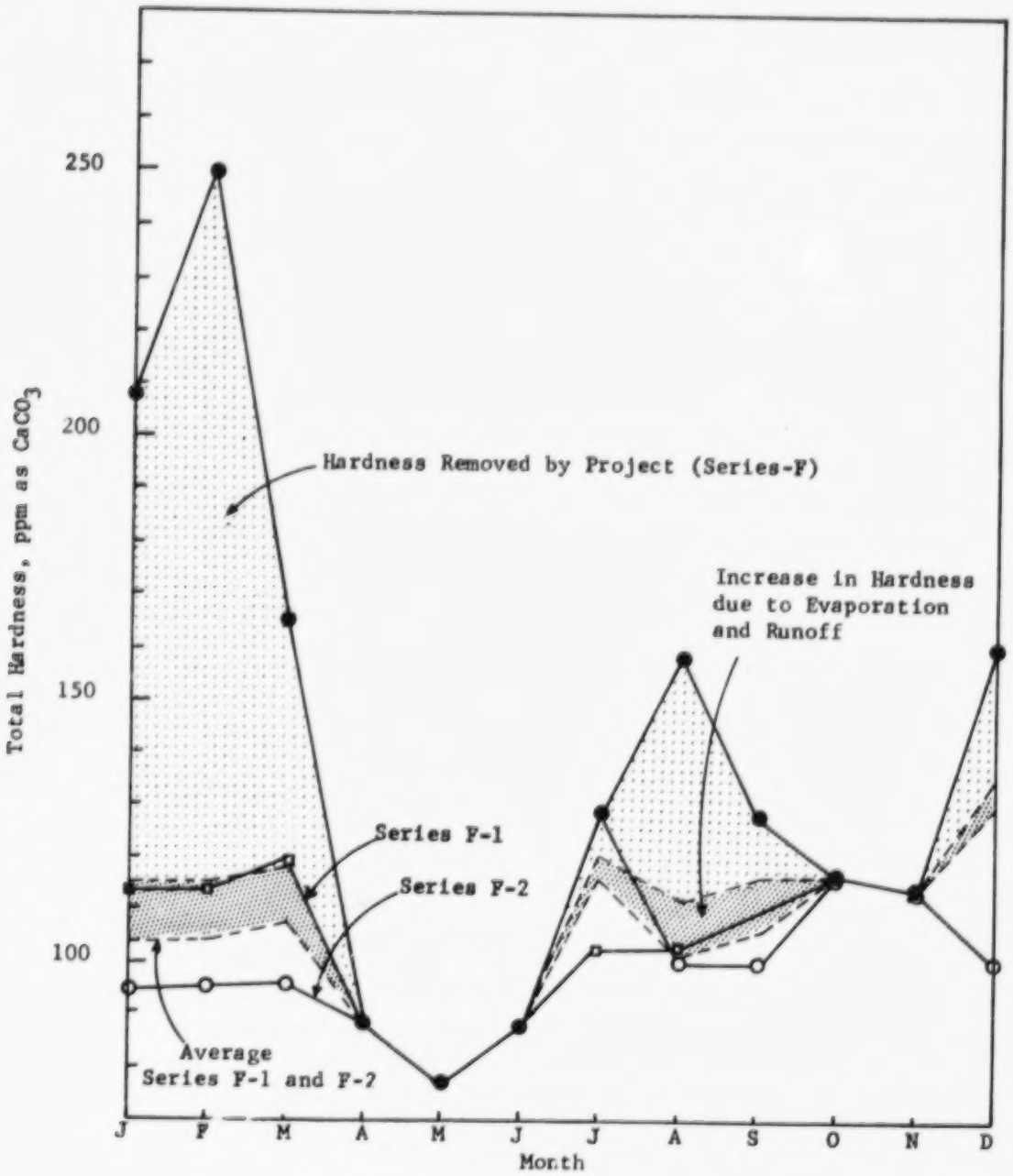


FIGURE-8 TOTAL HARDNESS - CONTRA COSTA CANAL
KELLOGG RESERVOIR OPERATION - SERIES-F
1968-1980

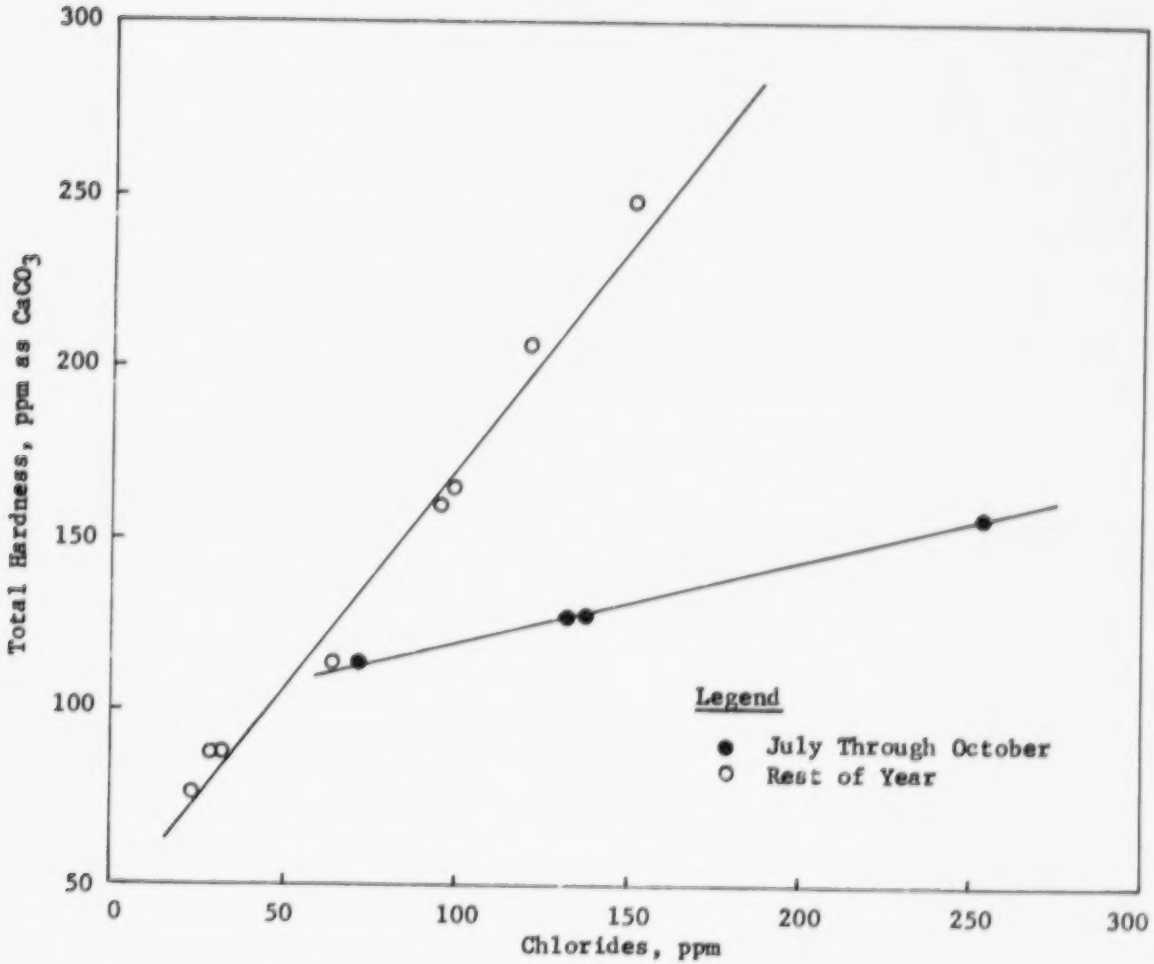


FIGURE-9 CORRELATION OF HARDNESS AND CHLORIDES
CONTRA COSTA CANAL
1959-1961 AVERAGE

hydrologically with the intrusion of salt water into the Delta during periods of low runoff.

A representation of the conditions subsequent to 1980 is represented in Figure 10 where Kellogg Reservoir operation is summarized for Series G based on conjunctive operation with the San Luis Project and the Department of Water Resources Delta Projects. The total hardness of available water delivered to the Contra Costa Canal subsequent to 1980 with these projects in operation will be drastically reduced, with the result that the benefits from the Kellogg Project with respect to the improvement of water quality will become comparatively small. In fact, total hardness delivered to the Contra Costa Canal would be generally below the critical level between economic and non-economic softening. In such a case, benefits might be virtually nonexistent.

Pollution Problems Associated with Storm Runoff. The probability that pollutants will be transported into the Contra Costa Canal by storm runoff creates a serious problem and demands consideration when studying quality improvement of the canal water. The nature of the terrain adjacent to the Contra Costa Canal is such that storm drainage readily enters the canal by natural drainage. Drainage also enters the system through storm drains which were installed to prevent erosion and damage to the canal linings at specific locations. Storm drains for subdivisions and other population concentrations also terminate in the canal. During the first years of operation this increased flow from drainage was a direct benefit to the irrigators who were the major water users at that time. Today, however, the main function of Contra Costa Canal has changed from transporting irrigation water to conveying water to municipalities and

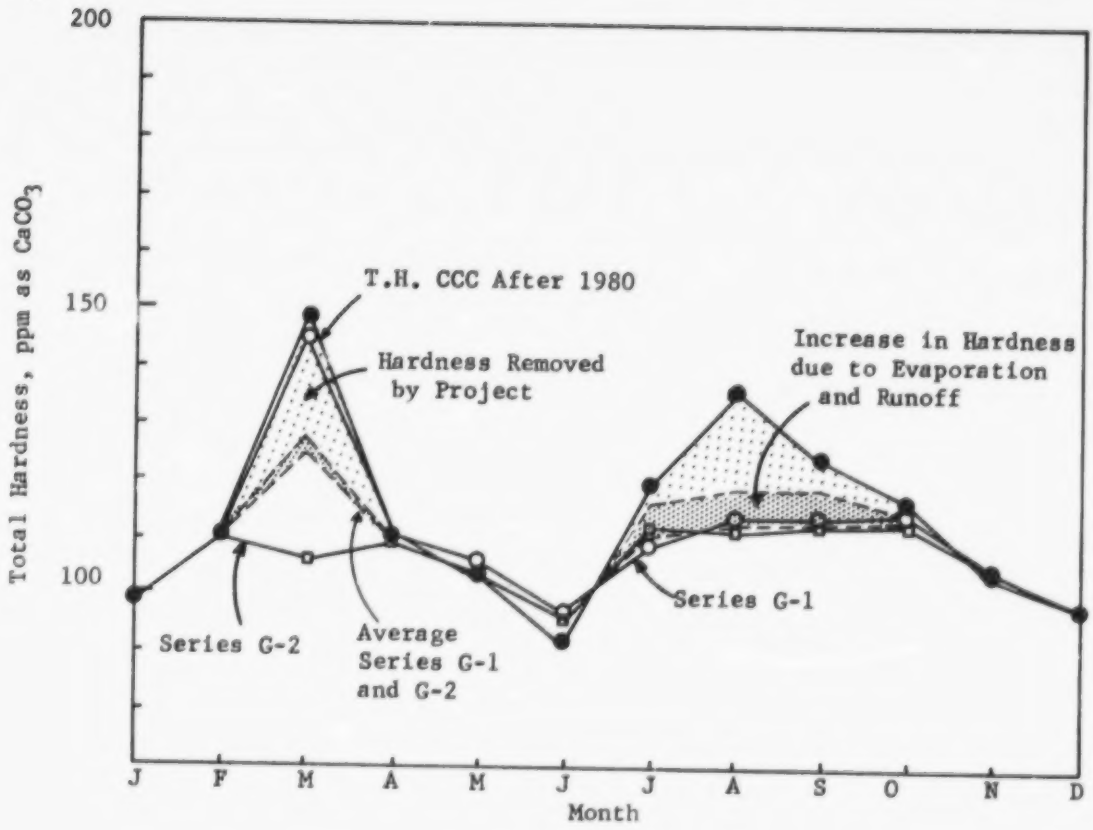


FIGURE-10 TOTAL HARDNESS - CONTRA COSTA CANAL
KELLOGG RESERVOIR OPERATION - SERIES-G
1980-2020
BASED ON OPERATION WITH SAN LUIS PROJECT AND DWR PROJECTS

industries which are the major consumers. Thus, the collection of runoff is no longer a benefit to the consumer, but a detriment because of the pollutants that are carried by surface runoff into the canal.

Contra Costa Canal has a tributary area of approximately 5,782 acres which can be divided into three distinctive classifications: (1) residential areas, (2) orchards, and (3) undeveloped grassland areas. These classifications have contributing runoff areas of 550 acres, 741 acres, and 4,491 acres, respectively. The runoff characteristics from each of the area classifications will be different in composition and, therefore, must be discussed separately.

1. Runoff from Residential Areas. The polluting effect of urban runoff has been well documented in the literature. It is an accepted fact that the storm drainage from streets, roofs, and other exposed portions of populated areas contain noxious substances which, if mixed in the water supply, can have a deleterious effect on public health. Many types of organic and inorganic materials are dissolved or suspended in the runoff. The more significant pollutants, from a public health standpoint, are bacterial contamination, nutrients (phosphates and nitrates), oil, gasoline, pesticides, and herbicides In addition, storm drainage usually carries a heavy load of silt, sand, and other debris.

The effects of these pollutants on water quality and on the ultimate consumers are numerous. Many of the toxic organic materials, including the pesticides and herbicides are highly resistant to biochemical degradation and will persist for long periods of time. The nutrients stimulate algal and other aquatic growth which cause taste and odor problems in domestic water supplies as well as increasing canal operation costs. Sediments and

other debris destroy the aesthetic qualities of the water in addition to causing many other problems.

No information was collected to substantiate the degree of pollution caused by urban runoff. However, sufficient evidence is available to demonstrate the potential danger from these pollutants. We therefore recommend that the following drains be relocated to eliminate any future problems:

a. Hillcrese Avenue Drains; two 10-inch concrete pipes drain Hillcrest Avenue and empty directly into Contra Costa Canal. Location of Hillcrest Avenue is at Contra Costa Canal mile 8.

b. All drains which collect runoff from subdivisions east and west of Railroad Avenue, near Pittsburg; in particular, the 24-inch corrugated metal pipes at canal miles 16.42 and 16.44 and the two 3' x 1' concrete conduits located at canal mile 16.48.

c. Wren Avenue Drains; in particular, the 8- and 12-inch corrugated metal pipes located at canal mile 31.75 and the 12-inch corrugated metal pipe which collects runoff from the Wren Avenue School at canal mile 31.73.

d. Bridge Road Drains; in particular, the two 8-inch concrete pipes which drain new subdivision located between Oak Park Boulevard and Boyd Road on Bridge Road.

e. Grayson Road Drains located at canal mile 40.95.

We also recommend that all existing backyard drains that allow surface runoff to enter the canal be removed and that no new drains of this type be constructed. The great quantities of fertilizers, pesticides, and herbicides used by the average suburbanite would, if discharged into the canal, create a serious public health problem. The nutrient effect of the fertilizers plus the toxic effect of the pesticides and herbicides could not be

tolerated. Consequently, a program to eliminate yard drainage into the canal is extremely important for maintaining the canal as a domestic water source.

2. Runoff from Orchard Areas. The use of pesticides on the orchards contiguous to the canal presents a real public health danger to the consumers of the canal water. Quantities of pesticides are applied annually to the pear and walnut orchards that are south of Contra Costa Canal and bordered by Ygnacio Canal and Walnut Creek. These chemicals can reach Contra Costa Canal through six concrete flap gates that collect surface runoff from the orchard areas. No data exist, however, to document the presence of pesticides in Contra Costa Canal, but the use of pesticides in other areas of the United States and the subsequent occurrence in watercourses indicates that a potential pollution problem exists.

The more toxic pesticides that are applied to the above-mentioned orchard areas belong to the chlorinated hydrocarbon and organic phosphate groups. The more toxic pesticides that belong to the chlorinated hydrocarbon group are Dieldrin, DDT, Heptachlor, Lindane, and BHC. Organic phosphates used in the orchard areas that drain into the canal are TEPP, Parathion, Systox, Malathion, and OMPA. Chlorinated hydrocarbons are believed to be more toxic than the organic phosphates and they have a long residual life. Organic phosphates are characterized by high potency and short residual life.

Based on computations using the rational formula and a 50-year rainfall intensity frequency, the surface runoff from the pear orchard, which is adjacent to Contra Costa Canal, is approximately 25 cfs. The runoff is contributed from an area of approximately 741 acres, and is approximately 20 percent of the design flow capacity of Contra Costa Canal at the point of runoff

concentration. The apparent runoff from the walnut orchards, located between Ygnacio Canal and Ygnacio Valley Road, is not included in the above runoff value. It is believed that Ygnacio Valley Road will inhibit runoff from reaching Contra Costa Canal. Potential pesticide problems originating from the walnut orchards, however, cannot be overlooked altogether since we cannot definitely state that surface runoff from these areas will not reach Contra Costa Canal.

Potential surface runoff pollution from the orchard areas will occur only during the months of greatest rainfall, notably, December, January, February and March. The rainfall in these months amounts to approximately 75 percent of the total annual precipitation. It is especially significant that the period of greatest pollution danger coincides with that time when the percentage of canal water used for domestic purposes is the highest. The main pesticide applied during this period is Parathion. It is possible, therefore, that traces of Parathion, a highly toxic chemical, will reach Contra Costa Canal. Also, traces of other pesticides, in particular the chlorinated hydrocarbons which have a long residual life, may reach the canal. The chlorinated hydrocarbons are applied primarily in the dry summer months, but because of their long residual life, these pesticides remain toxic through the months of greatest runoff and therefore may be carried in either a dissolved or suspended state by runoff to Contra Costa Canal.

A full evaluation of the effects of pesticides on the quality of water for human consumption remains to be made. However, pesticides are a serious potential pollution problem and it is for this reason that we recommend that the six concrete flap gates, located at canal miles 35.53, 35.73, 36.09, 36.50, 37.03, and 37.50, be eliminated and that surface runoff from the orchard areas be relocated to keep runoff from reaching Contra Costa Canal.

Pesticides may also reach the canal by drifting onto water surfaces of the canal during pesticide applications by the spray procedure. Therefore, every precaution must be made to guard against the drifting of pesticide sprays onto Contra Costa Canal water surfaces.

3. Runoff from Undeveloped Grassland Areas. Large quantities of storm runoff will come from the undeveloped grassland areas. The peak flow for a 50-year rain intensity frequency is estimated to be 214 cfs. A 25-year frequency rain intensity will produce a runoff flow of approximately 188 cfs. These quantities of runoff are greater than the canal design flows in most sections; however, they are maximum flows and are not likely to occur more than the specified frequency.

The undeveloped grasslands that contribute runoff into Contra Costa Canal are primarily used for cattle grazing. Only few cultivated farm lands are located on the slopes that drain to the canal. The surface runoff from this area should be of relatively high quality and should supplement the quantity of available water during the rainy months. However, any future change in these areas, either residential and industrial development or orchard and agricultural expansions, would make it necessary to eliminate or relocate all drains that collect surface runoff from these redeveloped areas.

To prevent the possible and probable pollution from surface runoff, the above recommendations should be carried out. These changes in drainage patterns will help maintain the high quality of water that will be supplied to Contra Costa Canal through the operation of the proposed Kellogg Reservoir.

IX. BENEFITS ATTRIBUTABLE TO WATER QUALITY IMPROVEMENT

Municipal Benefits

Nature of Benefits Derived. The operational programs for the Kellogg Project as preliminarily presented were directed primarily at achieving improvements in water quality as represented by chloride concentration. Because of comparatively good correlations between total dissolved solids and chloride concentration, it is to be expected that water uses requiring demineralization such as those of certain industries will show significant benefits as a result of the proposed scheme of operation. However, what may prove to be the optimum operation scheme for industrial water consumption may not prove to be optimum for municipal water use where softening (rather than demineralization) may be the important consideration. While concentrations of calcium and magnesium which cause hardness in water may be correlated with the concentrations of chloride ion at certain times of the year, the correlation is strictly seasonal. Thus, efforts to control chloride concentrations without regard to hardness levels during certain periods will yield reduced municipal benefits.

The operation of the Kellogg Project conjunctively with the Contra Costa Canal presents a number of interesting opportunities for economic benefits to municipal water consumers. It should be recognized also that it may create some problems. In the investigation which is presented herein, a number of potential benefits (and detriments) were examined but subsequently discarded as having comparatively little effect upon the economic feasibility of the project. Nevertheless, for purposes of documentation, a brief discussion of those factors is included. A few benefits, particularly those associated with hardness of water, were found to be economically

more important and were fully examined. Table 16 lists those factors considered to be significant in evaluating the benefits derived from improved water quality in the Contra Costa Canal in order of their relative importance.

Benefits of Reduced Hardness. The economic benefits derived from improvement in water hardness are associated with (1) reduction in the amount of soap or synthetic detergent necessary in household and commercial cleansing operations, (2) reduction in the cost of operation, servicing, and amortization of individual home softeners, and (3) reduction or elimination of costs attendant to operation, maintenance, and amortization of municipal water softening facilities.

A cursory examination of the water quality characteristics of deliveries to the Contra Costa Canal for project and non-project conditions indicated the impracticability of municipal water softening. Generally, the construction and operation of facilities for softening is regarded as economic only when the hardness exceeds 150 ppm as calcium carbonate. For the years 1959 and 1960, the average hardness of Contra Costa Canal deliveries at the head end was approximately 150 ppm, virtually on the borderline between economic and non-economic softening. Using this criteria, softening would be required for only about three months of the average year.

It is common knowledge that the amount of soap or synthetic detergent required for laundering purposes increases as the hardness of the water used increases. Thus, by reducing the hardness, direct savings in cost of these materials is realized. In addition, tangible benefits may be realized in reduced scaling of commercial equipment and municipal water lines, reduced scaling in household water heaters and other household equipment, and reduced deterioration of fabrics.

TABLE 16

SIGNIFICANT FACTORS IN EVALUATION OF BENEFITS TO MUNICIPAL WATER USE

Water Quality Characteristic or Constituent	Factor	Significance in Kellogg-Contra Costa Project
Total Hardness (Ca^{++} and Mg^{++} as $CaCO_3$)	1. Reduction in soap and detergent consumption	Important
	2. Reduction in home water softening costs	Important
	3. Reduce cost of municipal softening	Not applicable
Turbidity	1. Reduce flocculation chemical requirements (alum and lime)	Not possible to evaluate
	2. Extend filter runs	"
	3. Reduce backwash water	"
	4. Reduce prechlorination costs	"
	5. Increase filter loadings or decrease filter size	"
pH-Calcium-Alkalinity	1. Extend life of distribution system by control of corrosion	"
	2. Reduce corrosion control chemicals, lime	"
Chlorides	1. Reduce demineralization costs	Not applicable except to industrial users of municipal water
	2. Reduce tastes	Not important
Taste and Odor	1. Algae growth may increase taste and odor (detriment). Require copper sulfate treatment	Important

A recent comprehensive investigation of water hardness and domestic use of detergents in several Illinois cities by DeBoer and Larson (JAWWA, Vol. 23, July 1961) indicates that the savings on soaps, synthetics, general household cleansers, and other additives was about $1.15 per capita per year per 100 ppm of hardness removed. In these studies, however, the per capita water consumption only ranged from 40 to 60 gallons per day of which an estimated 27 gallons per capita per day were for uses requiring softening. It will be readily recognized that higher per capita consumption of water such as in Contra Costa County generally will result in greater per capita consumption of water necessitating softening. As between two waters of different hardness, an increase in per capita consumption will necessitate a proportional increase in total costs of softening chemicals per unit of hardness removed. In Contra Costa County in 1960, the average per capita consumption was approximately 135 gallons per capita per day as compared to an average in the Illinois cities surveyed by DeBoer and Larson of approximately 50 gallons per capita per day. While it is not expected that the consumption of water requiring softening would increase in direct proportion to the total water consumption, there must of necessity be some adjustment in the per capita costs reported by these authors for application to the Contra Costa County water hardness problem.

A preliminary comparison of costs of detergents, soaps, cleansers, shampoos, etc., for households in Contra Costa County utilizing water of an average hardness of 40 ppm, indicates total cost per capita of $12.00 per year in households without dishwashers. In an average 4-person family dwelling with a dishwasher and an automatic washing machine, the average per capita cost per year of detergents, soaps, and cleansers is approximately $14.50 (1960). This latter value may be compared to a total per

capita cost of $9.00 per year for these materials in the Illinois study for waters averaging about 40 ppm hardness. Thus, depending upon whether or not dishwashers are used, a ratio ranging from about 1.3 to 1.6 is obtained between softening costs in Contra Costa County and in the Illinois communities investigated by DeBoer and Larson. For purposes of this analysis, a factor of 1.5 was adopted. In the absence of more definitive information on the actual use of waters requiring softening, it is believed that this factor is sufficiently conservative, particularly in view of the fact that the ratio of per capita consumption of water is more than 2.5. Thus, it is estimated that the savings in soap, detergents, cleansers, etc., in Contra Costa County will be approximately 1.5 x $1.15 or $1.73 per capita per year per 100 ppm hardness.

In addition to the most apparent advantages of soft water to the home consumer in savings of softening materials, i.e., soaps and detergents, studies at Purdue University and in the Michigan Department of Health by J. Ringrose indicate the following benefits from softened water:

1. A 25 percent saving is realized on fuel for heating soft water by eliminating deposits of scale which retard heat transfer.

2. An 18 percent saving on repairing, cleaning, and replacing plumbing that is caked with scale is realized.

3. Fabrics show 25 percent less wear and tear when washed in soft water.

4. Soft water saves 16 percent wear and tear on utensils and reduces water spotting on glasses and dishes.

5. Food cooked in soft water retains its natural color and appearance and its digestive qualities.

6. In making tea and coffee it requires 50 percent less grounds in soft, as compared to hard, water.

7. Use of soft water for skin care provides less possibility for skin dryness and irritation. Toilet soap bars which are almost exclusively soaps, when used in soft water, do not cause severe soap deposits or scum on bath-tub or wash basins that must be removed by scouring powder and scrubbing.

Pomeroy (Report to City of Pasadena, 1950) has further analyzed these losses and has summarized them as shown in Table 17 below.

TABLE 17

MISCELLANEOUS SAVINGS FROM REMOVAL OF HARDNESS

Item	Savings Cents per Pound Hardness Removed
Reduced scaling in commercial and municipal water lines	0.4
Reduced scaling in household water heaters and other household equipment	0.4
Reduced deterioration of fabrics and other miscellaneous savings	0.3
Total Savings	1.1

The miscellaneous savings from removal of hardness amount to $0.45 per capita per 100 ppm per year. The total savings from soap and detergents plus miscellaneous costs is $2.18 per capita per 100 ppm per year.

Estimation of Economic Benefits Due to the Reduction in Total Hardness. Comparison of project and non-project total hardness curves for the various series and chronological periods results in the monthly average reductions in hardness reported in Table 18 below.

TABLE 18

AVERAGE CONTRA COSTA CANAL
MONTHLY REDUCTION IN TOTAL HARDNESS
Parts per Million

Month	1968-2020 Kellogg Project Alone	1980-2020 Kellogg Project with San Luis Projects and Delta Water Projects
January	92	-
February	133	-
March	48	18
April	-	-
May	-	-
June	-	-
July	7	5
August	44	20
September	11	10
October	-	-
November	-	-
December	24	-
Monthly Mean	30	4.4

The corresponding annual per capita savings which result from hardness reductions of 30 and 4.4 ppm are respectively $0.65 and $0.096.

Benefits from Home Softening. Howson (Journal AWWA, Feb. 1962) states that "at least 30% of the consumers use softeners when the public supply has 200 parts per million of hardness." This figure is quoted for an average annual hardness and does not appear to be valid for Contra Costa Canal water which only surpasses the 200 ppm level during a comparatively short winter season and usually for a period not exceeding two months. However, a survey of water softening firms in Contra Costa County showed that approximately 750 home softening units were in operation in Contra Costa County Water District service area. At the present population level, and assuming an average of 3.5 persons per household, this use represents approximately 1.75

percent of the entire population served by the canal. Rental and service charges amount to approximately $5.00 per month per household on the average, operation of the units being continuous throughout the year.

Savings may be realized by improving the quality of water in the Contra Costa Canal to the point where home softener services will not be required. It must be assumed in estimating such benefits that, (1) the percentage of the population serviced by softeners would not increase in the absence of the Kellogg Project, and (2) that when better quality water is made available the service would stop. Each of these assumptions may be reasonably questioned. In the first case, the rate of increase in softener use will depend on the activity of competing service organizations and on the sensitivity of the water consumer in future years to the need for softening. In the second case, it is probable that some people will use softeners whether needed or not; in fact, there are indications that strong sales campaigns have already achieved this goal in some areas. It is believed, however, that an analysis based on these assumptions is conservative. The total unit savings for individuals using home softeners, resulting from a decreased need for home softeners, is $17.03 per capita per year.

Effect of Turbidity on Municipal Benefits. The possibility that the Kellogg Project could effect benefits by materially reducing the turbidity of water delivered to the Contra Costa Canal was investigated. The possible areas in which savings might be affected include reduction of capital cost of construction for sedimentation and flocculation by municipal treatment plants, reduction in size of sand filters in municipal plants, or an increase in hydraulic loading, extension of filter runs or reduction in backwash, reduction in cost of alum and lime associated with the flocculation process, and

reduction in chlorine cost, particularly for prechlorination. A review of turbidities recorded for raw waters along the Contra Costa Canal indicated that water delivered to the Martinez treatment plant from the terminal reservoir of the canal is significantly improved on the average over that which is admitted to the upper end of the canal near Oakley. On the other hand, turbidities observed at intervening locations near Antioch and Pittsburg indicated abnormalities which were attributed to accretions of surface runoff or scour of previously deposited materials from the bottom of the canal. It is possible that with the development of Kellogg Reservoir and with proper attention being given to operation, some natural flocculation and sedimentation will occur in the reservoir which may work to the over-all benefit of municipal water users along the canal. Unfortunately, there is no way to predict reliably the turbidity which might be expected in water delivered from the Delta-Mendota Canal to the Kellogg Reservoir, much less the turbidity of water which might subsequently be delivered from the Kellogg Project to the Contra Costa Canal. In view of these uncertainties, and also in consideration of possible detriments which may result as a consequence of reservoir operation (as will be subsequently noted), it was not considered practical to attempt evaluation of benefits derived from improvement in turbidity of Contra Costa Canal waters.

Corrosion Control Benefits. If it were possible to selectively operate the Kellogg Reservoir so as to deliver to the various municipal distribution systems canal water which was slightly encrustive rather than corrosive, significant savings could be realized. These savings would be in the form of extended life of distribution system materials and reduction in chemical and operation costs for corrosion control. Unfortunately, it was not possible to undertake the necessary evaluation of these potential benefits

because of inadequate information on the quality of waters delivered through the Delta-Mendota Canal under future operating conditions and also because of the uncertainty of quality changes which might occur while the water was detained in Kellogg Reservoir. Decomposition of organic material and subsequent evolution of carbon dioxide could produce water potentially more corrosive than water supplied through the San Joaquin River to the Contra Costa Canal, and thereby yield a detriment rather than a benefit.

Benefits from Reduction in Chlorides. Benefits to municipal consumers from the control of chloride concentrations in the canal would be comparatively small except where industry uses large amounts of municipal water. The U.S. Public Health Service drinking water standards recommend that the chloride concentration of an acceptable water supply be maintained at less than 250 ppm. A review of chloride concentrations in Contra Costa Canal during the critical period 1959 to 1961 indicated that concentrations only rarely exceeded the recommended threshold, and seldom for more than a few weeks at a time. There will be some aesthetic advantages to water users of improved chloride quality in Contra Costa Canal water. These benefits are intangible in nature but nonetheless are important, real, and worthy of attainment. Benefits to industrial consumers who purchase municipal water have been treated elsewhere in this report.

Taste and Odor Control. The construction of Kellogg Reservoir for the improvement of water quality in the Contra Costa Canal represents a potential threat to the taste and odor characteristics of the water unless essential steps are taken to control the growth of algae in the reservoir. These costs must be considered as a detriment in a cost-benefit analysis of the Kellogg Project.

The normal period of algal production extends from the middle of April through the middle of October, during which time it is the usual practice to apply copper sulfate to the water in the reservoir. Applications of "bluestone" are usually precautionary rather than corrective and are carried out according to a predetermined schedule, usually about once every two weeks. Copper sulfate dosages are determined on the basis of the volume of water in the reservoir which is exposed to the most intense sunlight, often taken as the upper ten feet of the reservoir. Dosages are usually equivalent to 0.5 ppm of copper sulfate in this volume of water or an application rate of about 15 pounds per acre.

From the area-capacity curves for the proposed Kellogg Reservoir and assuming a bluestoning schedule extending from April 15 through October 15 at semi-monthly intervals, it was possible to calculate, from the reservoir operation sequences F and G, the probable amounts and cost of chemicals which would have to be applied and the cost of application. Chemical costs were computed to be $3,860 and $3,600 per treatment for Series F and G, respectively, or about $2.20 per acre per application. Application costs were based on recent experience of the East Bay Municipal Utility District with helicopters and was found to average about $0.45 per acre plus base-to-site costs. Total annual costs for copper sulfate treatment under Series F and G were, respectively, $57,000 and $53,200 (12 applications per year).

Summary of Benefits to Municipal Users. Table 19 presents the summary of benefits and detriments to municipal users of Contra Costa Canal water resulting from operation of Kellogg Reservoir alone and conjunctively with the San Luis Project and the Delta Projects of the Department of Water Resources.

TABLE 19

SUMMARY OF MUNICIPAL BENEFITS
RESULTING FROM IMPROVED WATER QUALITY
IN CONTRA COSTA CANAL
DUE TO OPERATION OF KELLOGG RESERVOIR

Period	Classification of Benefit or Detriment	Average Annual Per Capita Cost Savings
I. 1968-1980 Kellogg Project Alone	a. Reduced use of soaps, detergents, etc.	$ 0.65*
	b. Reduced use of home softeners	17.03**
	c. Taste and Odor control	-57,000.00***
II. 1981-2020 Kellogg Project in conjunctive operation with Delta and San Luis Projects	a. See above	0.096
	b. See above	---
	c. See above	-53,200.00****
III. 1981-2020 Kellogg Project Alone	a. See above	0.65*
	b. See above	17.03**
	c. See above	-57,000.00***

*Unit cost savings for 98.25% of population.
**Unit cost savings for 1.75% of population.
***Fixed annual cost (Series F).
****Fixed annual cost (Series G).

Industrial Benefits

Deterioration in the quality of the Contra Costa Canal waters has imposed increasingly severe economic penalties on the industrial users. Additional water treatment processes must now be used during periods of poor water quality and other production expenses are also incurred. During a recent severe period of poor water quality, July and August of 1959, one of the major industrial users was forced to suspend all production until a better quality of water again became available. The degradation of water quality in the Contra Costa Canal water service area has undoubtedly caused other major industries

to reject this area as a site for new facilities and to seek other more desirable, and perhaps otherwise more expensive, locations. In any event, the decreasing quality of the Contra Costa Canal waters is resulting in increasing economic costs to both industries and consumers.

Data relative to water quality penalty costs incurred by industry were obtained from the majority of industrial water users in the Contra Costa Canal service area (see Tables 20 and 21). These data represent the reported penalty costs incurred by industry in 1961 due to chloride content in excess of 100 ppm and/or total dissolved solids greater than 400 ppm.

The results of the industrial survey for annual penalty costs are presented in tabular form in Table 20. It is noted that results fluctuate from a very rough, and undoubtedly low, estimate of $1,000 per year to a detailed estimate of $158,700 per year. The total 1961 penalty costs were found to be $354,250. This figure is believed to be low as not all major industries replied, and several of those that did reply submitted only cursory guesses. Furthermore, annual fixed charges on required additional water treatment and/or process equipment, a major item, were supplied by only two industries.

The conversion of annual penalty costs to average penalty costs per acre-foot of poor quality water processed is shown in Table 21. Although individual industries may incur penalty costs of several hundred dollars per acre-foot during brief periods and for relatively small quantities of water, a more useful over-all per acre-foot penalty cost is obtained by dividing the total annual penalty cost by the total Contra Costa Canal water usage of the included industries. This penalty cost is then $8.36 per acre-foot, excluding fixed charges.

TABLE 20

INDUSTRIAL ANNUAL PENALTY COSTS INCURRED IN 1961
ATTRIBUTED TO CONTRA COSTA CANAL WATER QUALITIES
IN EXCESS OF 100 PPM CHLORIDES AND/OR 400 PPM TOTAL DISSOLVED SOLIDS

Increased Cost Attributed To:	Increased Costs Per Year - Dollars Reporting Industry									
	A	B	C	D	E	F	G	H	I	J
High Canal Turbidity				3,500		1,500				
Corrosion and Scale Build-Up			5,000					900		
Water Softening	6,900		10,000	500						
Deionizing	69,000			3,400		900				17,000
Boiler Feedwater			2,000				1,200			
Boiler Blow-Down	30,200		4,500							
Cooling Tower Blow-Down	2,900		6,000			250		200		
Additional Plant Equipment Operating Losses	49,700				9,100					
Fixed Charges on Additional Equipment			25,000		9,000					
Product Losses				26,000						
(Not Categorized)		68,600							1,000	
Totals	158,700	68,600	52,500	33,400	18,100	2,650	1,200	1,100	1,000	17,000

SUM OF TOTALS = $354,250

TABLE 21

INDUSTRIAL PER-UNIT PENALTY COSTS INCURRED IN 1961
ATTRIBUTED TO CONTRA COSTA CANAL WATER QUALITIES IN EXCESS
OF 100 PPM CHLORIDES AND/OR 400 PPM TOTAL DISSOLVED SOLIDS

	Reporting Industry										Total or Average
	A	B	C	D	E	F	G	H	I	J	
Total* 1961 canal water penalty costs of canal water requiring additional treatment	$158,700	$68,00	$27,500	$33,400	$9,100	$2,650	$1,200	$1,100	$1,000	$17,000	$320,250
Total 1961 canal water requiring additional treatment, AF	1,980	4,700	210	1,028	31	28	33	297	224	60	8,611
Total 1961 canal water usage, AF	11,291	9,257	1,030	2,557	3,639	109	657	1,234	995	7,545	38,304
Average 1961 canal water penalty cost per AF of canal water requiring additional treatment	$80.15	$14.60	$130.95	$32.49	$293.55	$94.64	$22.64	$3.70	$4.46	$284.00	$37.19
Average 1961 canal water penalty cost per AF of total canal water usage	$14.07	$7.41	$26.70	$13.06	$2.50	$24.31	$1.83	$0.89	$1.01	$2.25	$8.36

*Excluding fixed charges on additional equipment.

The above industrial data are for the year 1961. During this period there were five months when the chloride concentrations were in excess of 100 ppm. The excess averaged about 70 ppm. However, a 3-year water quality average has been selected as a basis for this report, and during this time the average excess chlorides were 64 ppm. Assuming that there is a linear relationship between the quantity of water treated and the amount of chlorides in excess of 100 ppm, it is possible to correct the unit penalty cost. This adjustment is accomplished by multiplying the unit penalty cost for 1961 by the ratio 64/70 which gives $7.65.

For later periods when it can be assumed that either or both the San Luis and the State's Delta project will be in operation, an additional adjustment of the penalty cost is necessary. Both of these projects would have a decidedly beneficial effect on the water quality in the Delta and would therefore cause a further reduction in the industrial penalty costs. According to the projected water quality data, there would be only two months with chloride concentrations in excess of 100 ppm. The average excess during this period is 38 ppm. To make this comparable to the earlier computations the excess chlorides should be spread over the 5-month period which amounts to 15 ppm. Using the assumption of a linear quantity-chloride relationship, the penalty costs after completion of these projects would amount to 15/70 of $8.36, or $1.79.

It is therefore recommended that the computation of industrial benefits attributable to water quality improvement be based on a penalty cost of $7.65 per acre-foot of water diverted from the canal for industrial use up to the date the San Luis and Delta projects are in operation. For the period thereafter, it is recommended that a penalty cost of $1.79 per acre-foot be used.

In addition to the above tangible benefits there are additional benefits not really subject to monetary evaluation. These are effects which could accrue in the absence of water quality control, including such damages and restrictions as preclusion of economic activities and loss of industrial and agricultural production.

Agricultural Benefits

The problems associated with determining agricultural benefits derived from the improvement of water quality are many and complex. For example, good drainage of the soil may be a more important factor for crop growth than the quality of water in the irrigation supply. Also, excellent water may be of inferior quality for irrigation use; in fact, water quality criteria, from the viewpoint of soil and plant relationships, differ in many respects from the criteria for domestic or industrial waters.

Table 22 shows the general classifications of irrigation water. Present quality of Contra Costa Canal water is such that for all months of the year except August, it meets the requirements for Class I irrigation water. In August, the maximum average chlorides is 248 ppm or 7 m.e./l, which indicates a Class II irrigation water.

Projected water quality characteristics due to improvement from the Kellogg project indicate that water supplied to agriculture will be a Class I irrigation water year round. Thus, there is a potential benefit to the agricultural user from water quality improvement. However, the determination of this benefit is not possible with the information presently available.

TABLE 22

QUALITATIVE CLASSIFICATION OF
IRRIGATION WATERS*

Chemical Properties	Class 1 Excellent To Good (Suitable for most plants under any conditions of soil and climate)	Class 2 Good to Injurious (Possibly harmful for some crops under certain soil conditions)	Class 3 Injurious to Unsatisfactory (Harmful to most crops and unsatisfactory for all but the most tolerant)
Total dissolved solids			
In ppm	Less than 700	700 - 2,000	More than 2,000
In conductance EC x 10^6	Less than 1,000	1,000 - 3,000	More than 3,000
Chloride ion concentration			
In milli-equivalents per liter	Less than 5	5 - 10	More than 10
In ppm	Less than 175	175 - 350	More than 350
Sodium in percent of base constituents	Less than 60	60 - 75	More than 75
Boron in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

*Anonymous

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